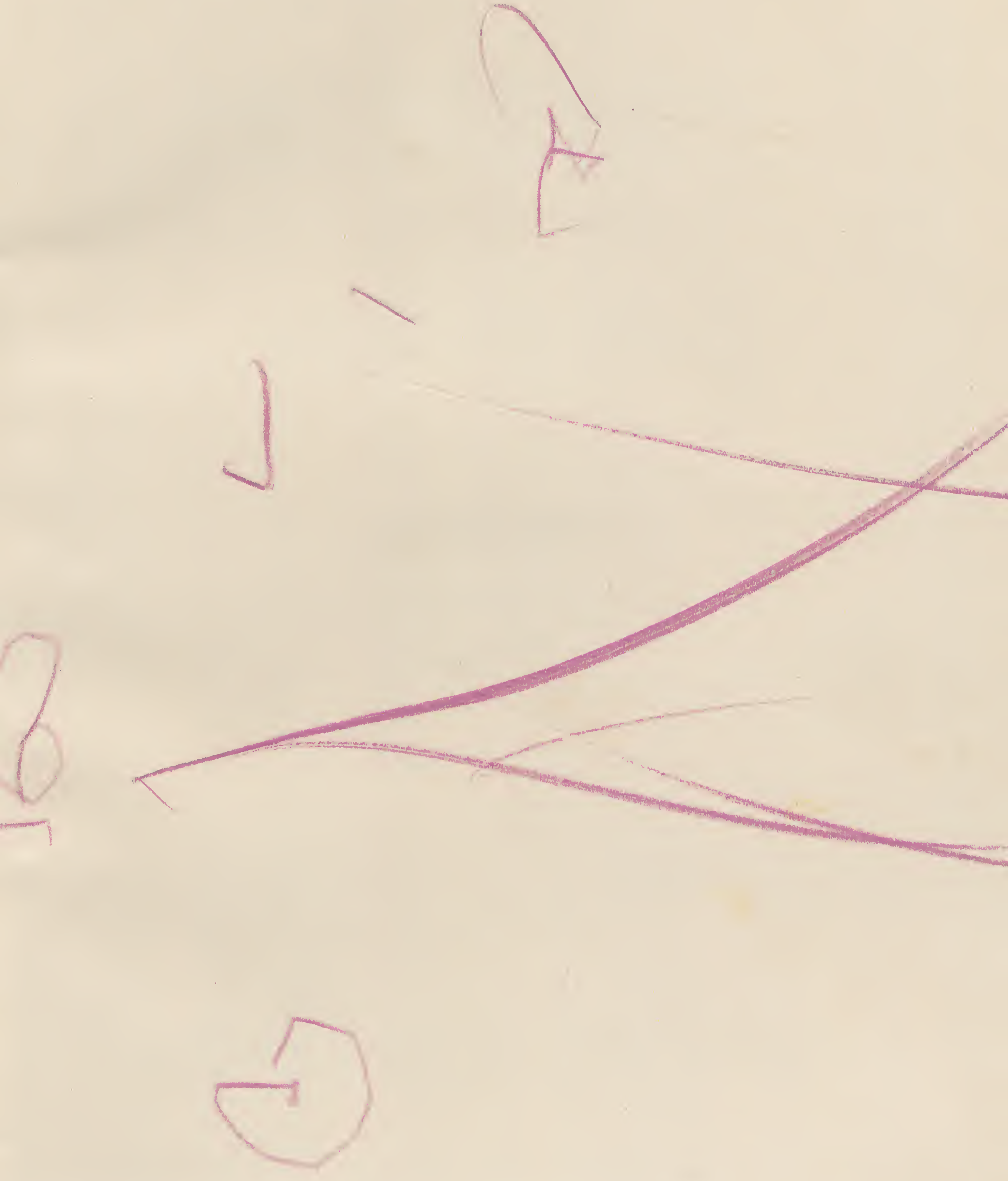

MODERN PRACTICAL BUILDING

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CHAPTER 1

STAIRS AND STAIR-BUILDING

THEORY

THE stairs or steps are themselves composed of horizontal and vertical boards, joined together at right angles, and known, as will be described later, as *Treads* and *Risers*, attached at their ends to sloping planks known as *Strings*, which extend either from one floor to another in a continuous length or from one floor to landings spaced at convenient heights between the floors.

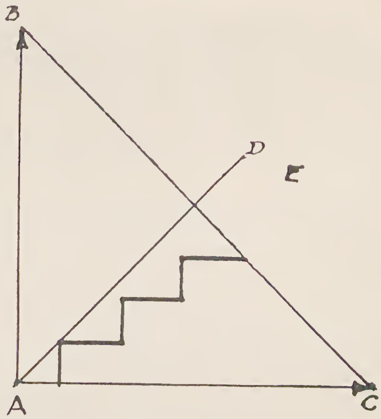


Fig. 1.—Designing stairs. Angle AE should be less than 45°.

The angle the stairs make with the horizontal should be less than 45° for safe and easy use. Consequently, the steps in a stair are made with the treads wider from front to back than the height of the riser. Staircases which, owing to the lack of horizontal space, have to be constructed with the rise greater than the tread are very tiring, and should never be employed for ordinary conditions of use. On the other hand, a staircase having a tread of a depth too much in excess of the height of the riser is almost, if not quite, as tiring as the too-steep one. This is shown in Fig. 1, where AB represents vertical progress, and AC horizontal progress; the bisecting line would be AD, or an angle of 45°, but the angle AE gives greater ease.

Whilst there are certain rules which experience has proved to serve as guidance in this matter of the proportion of tread to riser, and which will be detailed later, in passing it may be mentioned that a rise of about $7\frac{1}{2}$ inches to a tread from 9 inches to 11 inches forms the most comfortable and convenient ascent.

PLANNING

The space available on plan is a deciding factor in the disposition of a staircase, for obviously where space is unrestricted the cheapest form of stair and the easiest to construct would be one consisting of a single flight and running in one direction at the required angle from floor to floor. However, such a stair is not satisfactory in appearance, and in the ordinary-sized house there is rarely sufficient horizontal space for its accommodation. Consequently, the stairs have to be built in two or more flights, running in two or more directions, in order to make the most use of the horizontal floor space.

And as will be clear, the form of stair most economical of space is that used in ascending a turret, known as a circular geometrical stair, which rises round a single circular newel, the line of ascent being a vertical spiral.

In actually drawing the sectional outline of the ascent of a flight of stairs the designer, having already fixed his height from floor to floor, must indicate on his lower floor line the horizontal space which he will have at his disposal, and assuming that a rise of $7\frac{1}{2}$ inches has been decided upon, he will divide the vertical height by $7\frac{1}{2}$ inches, and the result will give the number of risers required in the flight, and the number of treads will be one less than this. So that the horizontal space required for the accommodation of the treads will be that of the depth of a single tread multiplied by a number one less than the number of risers. The reason for this being one less is because the top step is the floor.

The *Rise* of any step is found by dividing the total rise, *i.e.* the vertical distance from floor to floor, by the number of risers, and the run of the stairs may be fixed at will. The *Run* is the horizontal distance from the face of one riser to that of the one immediately above it. The rise of a stair is that vertical distance from the top of one step to the top of the next.

Therefore, bearing in mind what has already been said as to comfort of ascent, the run may be fixed at will; and the simple rule of thumb which has already been given with regard to this proportion should be qualified to the extent that whilst for adults a rise of from 7 inches to $7\frac{1}{2}$ inches will be found the most comfortable, a 6-inch rise should be made use of in schools or on stairs used mainly by children.

Rules.—Of the several rules for proportioning the run to the rise, the following may be quoted:

1. The sum of the rise and run should equal 17–$17\frac{1}{2}$ inches.
2. The sum of two risers and a tread should be not less than 24 inches, and not more than 25 inches.
3. The product of the rise and run should be not less than 70 inches, and not more than 75 inches.

DEFINITIONS

The following definitions of the terms used in connection with stairs are given in Mowat's *Stairbuilding and Handrailing*:

"*The Step* of a woodstair consists of two parts, the one termed the tread and the other the riser.

"*The Tread* is the horizontal part of the step upon which the foot is placed.

"*The Riser* is the vertical part of the step, and connects the front of one tread with the back of the next below it.

"*Nosing* is the outer edge of the tread which projects beyond the outer face of the riser. It is usually rounded, chamfered, or moulded, and when so treated is termed a moulded nosing (see Fig. 22).

"*The Going* of a step is the horizontal distance between the outer faces of two consecutive risers (see Fig. 2). This term is not often used, the distance referred to being generally spoken of as the "width of tread," or shortly, the "tread."

"*Rise.*—The vertical distance between the upper surfaces of two consecutive treads.

"*Fliers.* — Steps of uniform or parallel width used in the straight portions of steps.

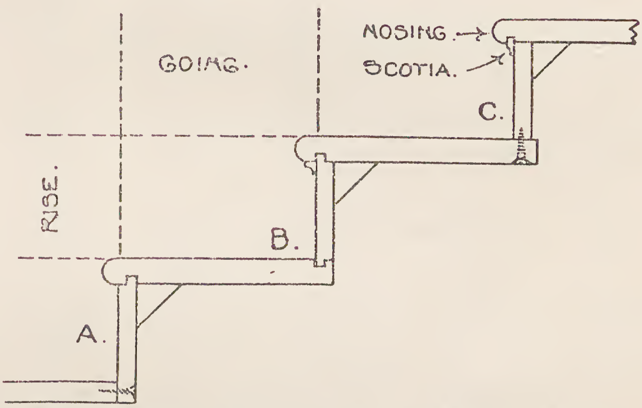


Fig. 2.—Definitions explained—A, B, and C show different methods of fixing the riser to the tread.

"*Winders.*—Steps that are narrower at one end than the other. They are employed in turning corners or going round curves.

"*Flight.*—A succession of steps uninterrupted by a landing.

"*Landing.*—A horizontal platform introduced in the course of the ascent as a convenient resting-place, and affording a means of effecting a change of direction of the stair. It thus forms the termination of one flight as well as the start for the next.

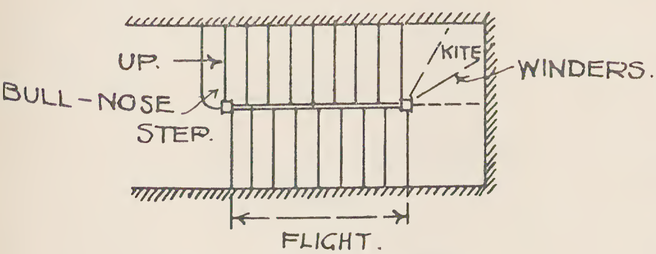


Fig. 3.—Definitions explained.

"If a complete half-turn has to be made on the landing between the termination of one flight and the start of the next, it is then termed a *Halfspace Landing*, and if only a quarter turn, it is called a *Quarter-space Landing*.

"The term 'landing' is also applied to the portion of the floor immediately adjoining the top or bottom of a stair.

" *The Going of a Flight.*—The horizontal distance between the faces of the first and last riser of a flight. Sometimes also called the *Run* of the flight. In circular stairs the measurement is made on a line 15–18 inches from the handrail, over the narrow ends of the steps.

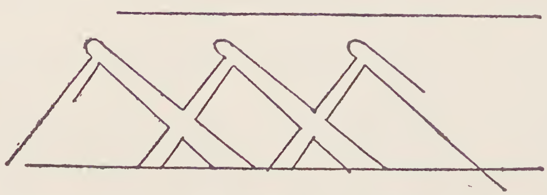


Fig. 4.—String showing housing for treads and risers.

" *Strings or Stringers.*—The raking or inclined pieces which support the ends of the steps. Of these there are several sorts.

" 1. *Cut Strings* are simply notched out on their upper edges to receive the treads and risers (Fig. 5). They are only used for the roughest class of stairs.

" 2. *Cut and Mitred Strings.*—These are notched out as in the preceding, but the ends of the risers are mitred against the vertical parts of the notches.

" 3. *Cut and Bracketed Strings.*—In these the ends of the risers mitre with ' ornamental brackets,' nailed to the face of the string.

" 4. *Housed Strings.*—The upper edges of these strings, instead of being notched out as in the previous examples, are made parallel to the lower edges, and housings cut in the inner sides to receive the ends of the treads and risers (see Fig. 4).

" 5. *Open and Close Strings.*—Cut and mitred strings, and cut and bracketed strings defined above, are often termed open strings, the ordinary string, having parallel top and bottom, being termed a close string.

" 6. *A Wreathed String* is one that, while it follows the inclination of the stairs, winds round a vertical cylindrical surface. For instance, the strings of a spiral staircase, or again the curved string carried round the well-hole of a geometrical stair, are wreathed.

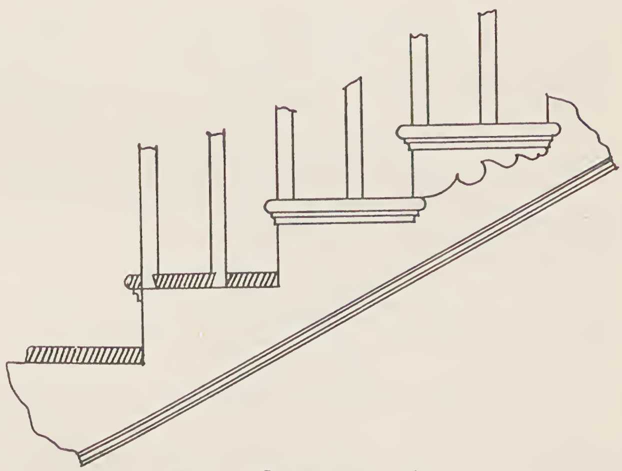


Fig. 5.—Cut or open string.

" 7. *Rough Strings.*—These are rough scantlings fitted below the steps between the finished strings, to provide additional support and stiffening to the stair, rendered necessary when it exceeds 3 or 4 feet in width. *Carriages* and sometimes *Spring-trees* are terms also applied to these timbers.

"Strings are also distinguished by their relative positions as 'outer string,' 'front string,' 'well string,' 'wall string'; in ships 'bulkhead string,' the meaning of which being obvious, no explanations are required.

"*Easings.*—The curves formed on the edges of strings where they meet at different inclinations, or again, where a pitched string joins in with the level skirting, are called easings, and may be parts of circles or any other agreeable curves.

"*Well, Well-hole.*—The clear, vertical, central space round which the stair turns.

"*Stair Handrails* are rounded or moulded bars for holding on to by the person ascending or descending the stair. They are placed over the ends of the steps at a height from them convenient for the hand to grasp, being made to conform throughout their length to the inclination of the stair.

"*Balusters* are light pillars for supporting the handrail and for filling up the space between the latter and the stair steps to prevent persons from falling through.

"*Balustrade.*—The framework formed by the combination of rail and balusters.

"*Newels.*—The posts or columns used in some kinds of stairs at the turnings to connect the handrails and strings of adjacent flights. The term newel is also applied to the post or final baluster at the bottom of a stair which terminates a balustrade. In a spiral staircase built round a central post or pillar, the post is referred to as a newel.

"*Curtail or Scroll Step.*—The bottom step of a stair is so named when one or both of its ends project beyond the strings so as to stand under the spiral scroll of the handrail, with which they should be made partly to agree in plan.

"*Bull-nose Step.*—The bottom step of a stair projecting as above, but having its ends semicircular. A step with a quarter-circle end is also sometimes called a bull-nose.

"*Commode Step.*—A combination of two round-ended steps one above the other, standing under a newel at the start of a stair."

PARTS OF WOODEN STAIRS—CONSTRUCTION EXPLAINED

The following additional definitions are necessary in explanation of the structural details of staircases. It should be remembered that a wooden staircase in its simplest form is in the nature of a ladder, and though the treads and risers are built in solid, the actual part on which the foot rests in ascending and descending a stair is very little wider than the rung of a ladder. The resemblance is further carried out in the fact that the treads and risers are supported at their ends by wide boards which perform the same function as the poles used to form a ladder.

A String is the name given to the board affording this support at the sides, that against the wall being known as the *Inner or Wall String.*

That on the side farthest from the wall is termed the *Outer String.*

The ends of both the tread and the riser are housed into the inner and outer strings, being let into wedge-shaped grooves called *Housings.* Into these housings are driven wedges of oak or other hardwood, the housing being undercut, and the edge of the wedge cut in accordance to fit against it as in a dovetail joint.

Nosing Line.—In construction a line is drawn on the inner face of the string touching the top angles formed by the junctions of the treads and risers. The line of the nosings is to be distinguished from the nosing line as being the line drawn touching the rounded edgings of the treads. The tread is usually cut out of $1\frac{1}{2}$-inch boarding, and its actual horizontal depth from back to front is the distance of the face from one rise to another, plus the depth of the rounded nosing which is projected beyond the face of the riser below plus the thickness of the riser, plus, in many cases, a further projecting horn of about $\frac{3}{4}$ inch beyond the back of the riser.

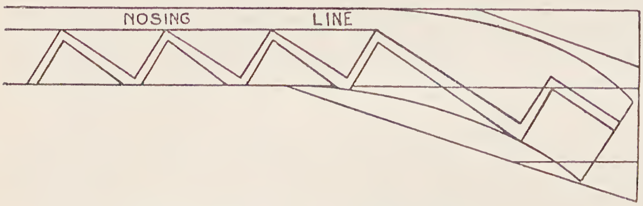


Fig. 6.—String and nosing line.

On the underside of the nosing, in better-class work, it is usual to fix a moulding known as a *scotia* (Fig. 2), which is let into a groove cut in the under-surface of the tread and fitted tight against the top of the riser. This moulding serves the purpose of concealing the joint between the tread and the riser, and at the same time it secures the head of the riser to the under surface of the tread without additional cutting of the tread. Alternatively, the top of the riser is rebated on its top outer edge and let into a groove cut in the underside of the tread, the joint being concealed by a *Cavetto Moulding* let into the angle and sprigged.

The joint between the bottom of the riser and the tread may be a simple butt joint screwed, either with the tread butted against the bottom of the riser or with the bottom of the riser butted against the end of the tread. Or alternatively, the bottom of the riser is rebated to fit into a groove cut in the upper surface of the tread, and the end of the tread may or may not be extended past the inner face of the riser, as has been already mentioned.

Carriages.—Complaints are often made that the steps of a staircase creak some time after they have been built in ; and whilst this is due in the main to the shrinkage of the ends of the treads and risers, causing them to become loose in the housings cut in the strings, and could be cured in most instances by driving in the hardwood wedges already mentioned, yet it is more often due to the omission of additional

support to the undersides of the treads and risers that is required to all staircases where the width is over 2 feet 9 inches. This additional support is afforded by pieces of $4\frac{1}{2} \times 2$-inch quartering which are known as *Carriages* and are inserted underneath the treads and risers, being notched out to receive their inner angles. There may be one or two or more of these carriages, in the width of a staircase, the number required depending upon the width. Carriages are fixed in all classes of work under steps known as fliers. An additional purpose served by these carriages is that they afford a fixing for the laths to be nailed to for plastering the underside or *soffit* of the stairs.

Bracket.—An alternative method of supporting the treads by the carriages is to fix a piece of wood about $\frac{1}{2}$–$\frac{3}{4}$ inch in thickness cut square at one end and at an angle the same as that of the stairs at the other end, and to nail the end cut to an angle to the side of the carriage, the upper edge coming up against the upper surface of the tread. The term *Bracket* is also used in description of the moulded or cut pieces tacked on to the side of a string of an open stair for decorative purposes, but this has no structural value.

Blocks.—As an additional strengthener to the inner angle formed by the treads and risers, triangular blocks of wood are glued in. These serve the purpose of stiffening the joint and keeping the rebate on the riser tight up against the outside edge of the groove cut in the underside of the tread.

The Wall String is worked on one face only, and the method of setting this out will be found in detail later. The housings should be cut $\frac{3}{8}$ inch deep and at the angles formed by walls at right angles, as on a landing the two strings are rebated and grooved.

Bull-nose Steps.—These are steps in which the risers are formed in a circle or ellipse, and are situated as a rule at the bottom of a flight. They are formed by the face of the riser being cut very thin to form a veneer to enable it to be bent round a rounded block, which is usually formed in three thicknesses one above the other. Rebates are cut in each side of the housing of the riser face, and the rebate next the newel is undercut to give it a hold on the block.

FITTING THE STAIRS

The ends of the treads and risers being housed into the wedge-shaped grooves cut in the inner and outer strings as has already been explained, the flight is then framed together and cramped in an apparatus known as a saddle cramp. When the strings are thus tightly cramped into place, the nosing line must be tested to see that none of the nosings are out of winding. This is done by laying a straightedge up the flight resting on the nosings, and any nosing that does not touch the straightedge should be knocked up tighter. The hardwood wedges may then be glued and driven home and trimmed flush. The blocks explained

above are then glued and inserted into the angles, formed by the treads and risers, those against the strings being glued at their ends to secure them to the strings, as well as on their faces touching the treads and risers.

The junctions between the treads and risers may either be nailed or screwed, and in first-class workmanship the treads are screwed to the outer string on the skew.

On the landing a newel is framed up to the trimmer, and into this the outer string is housed. The wall string should terminate by being

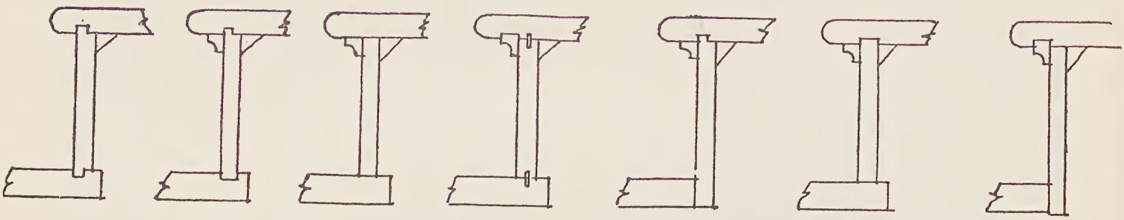


Fig. 7.—Various methods of jointing treads and risers.

housed into a half newel fixed to the wall, although in cheaper class work the half newel is omitted and a string is eased into the skirting. This latter method, however, often gives rise to botched work where the moulding on the skirting is different from that on the string, as it frequently is when the staircases are bought ready made out of stock.

The landing nosing and the riser below it, and part of the tread of the step below, will cut on to the inner face of the newel, which will require a housing to be scribed out to take these ends. The ends are nailed into the housing from the back.

SETTING OUT A STAIRCASE

For simplicity the following description refers to the setting out of a straight flight, and it may be as well to mention here that for a staircase to be set out satisfactorily, the measurements should be taken from the actual job, and the floors should be completed before any staircases are fixed. The first necessity is a rod known as a *Storey Rod*, which is a batten about 2 inches square and long enough to extend from floor to floor (Fig. 21).

The storey rod is dropped vertically down the face of the trimmer to the floor below to a point vertically underneath it. This point must be obtained by a plumb line and bob, and marked in chalk on the lower floor, the line of the upper end of the plumb line being marked on the side of the trimmer. The point at which the floor boards on the upper floor cut the storey rod is then marked on the rod. The storey rod must then be divided equally by means of carpenter's dividers into as many divisions as there are risers shown on the eighth scale drawings—the top one being marked UP. The side of the rod on which these divisions figure is then marked RISE. Now the rod is laid against the plaster of

FIG. 8.—A GEOMETRICAL STAIRCASE.
(Courtesy of John Sadd & Sons, Ltd.)

Fig. 9.—ENTRANCE HALL IN THE JACOBEAN STYLE.
(T. P. Bennett & Son, FF.R.I.B.A., Architects.)

the end wall if the wall is rendered, or an allowance is made of an inch if it is not, and a distance from such end wall to the trimmer is marked on the other edge of the rod. The position of the first riser is also marked on this side of the rod, and is lettered START. The distances of any openings from the cross wall, such as doors and windows, are also marked on the rod, with references as to what the marks refer.

The Position of the Risers should be marked on the storey rod in equal divisions, and if there is a landing in the flight, this of course must be indicated. The bottom newel is situated as a rule so that its centre line comes flush with the face of the second riser, whilst the landing and top newels are placed centrally on the top riser in each instance.

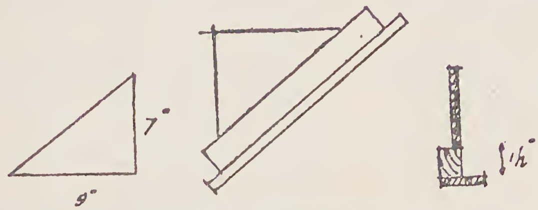


Fig. 10.—Pitch board.

Pitch Board.—This template or set square formed of two pieces of wood jointed at right angles is required for setting out the strings. At the bottom edge of the pitch board a strip is fixed of the width of the margin, and another strip is tacked on or housed into this at right angles, to act as a gauge for the pitch board to enable the correct angle of the lower edges of the joints between the risers and treads to be marked on the string.

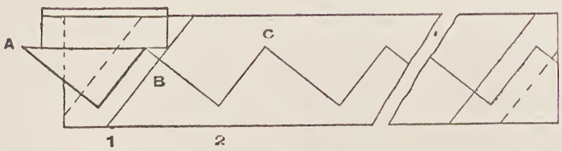


Fig. 11.—Marking treads and risers.

It will be remembered that the housings for the treads and risers are wedge-shaped, and whilst the tops of these housings are vertical the under edges are at an angle. The angle between the two mortises is 82° instead of 90°. For use with this pitch board are two other templates, one the riser template, being the length of the riser and its width, plus the space of the wedge, and the other the tread template, which is

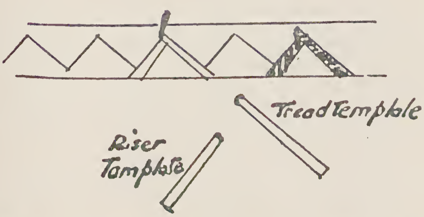


Fig. 12.—Marking housings for treads and risers with templates.

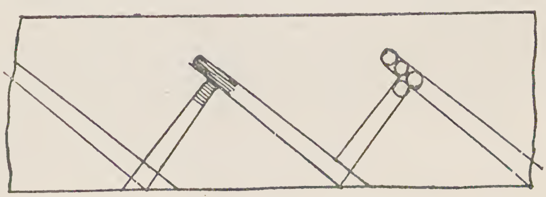


Fig. 13.—Cutting the housings.

made of similar dimensions, *i.e.* the width of the template plus the space to be occupied by the wedge.

In marking out these are laid on the single lines already marked by

the pitch board, and a line along their lower edge gives the dimensions of the wood to be cut away for the housings for the treads and risers.

To find the length of the string necessary, multiply the longest edge of the pitch board by the number of steps, adding the distances necessary to meet the skirting or strings at right angles. It is usual, however, to make strings longer than will be required, and to fit them on the job.

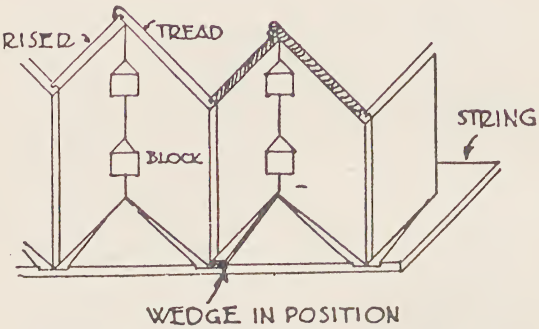


Fig. 14.—Treads and risers wedged and blocked.

The method of cutting the housing to receive the ends of the treads and risers, which are about $\frac{3}{8}$ inch deep, is to bore holes side by side within the markings with a brace and bit, and then to remove the remaining wood with the chisel, after the sides have been cut with a tenon saw. The bottoms of the groove so formed should be smoothed with a router.

When the top and bottom ends of the strings are to be cut they must be formed with a shoulder leaving a tenon of at least $\frac{1}{4}$ inch from the face of the string. This tenon should be at right angles to the face of the newel, and when in position should be pinned with a hardwood pin through a hole bored in the newel.

A more rough-and-ready method of laying out the treads and risers on a string is to use the steel square on which the inch marks will give

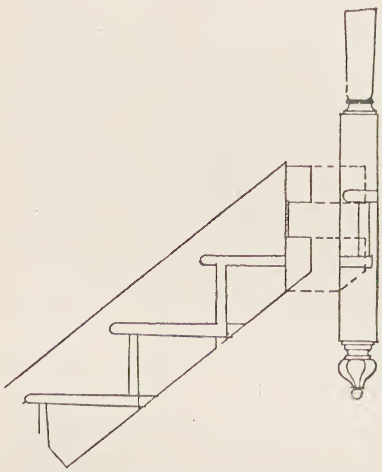


Fig. 15.—Method of fixing string to newel at top.

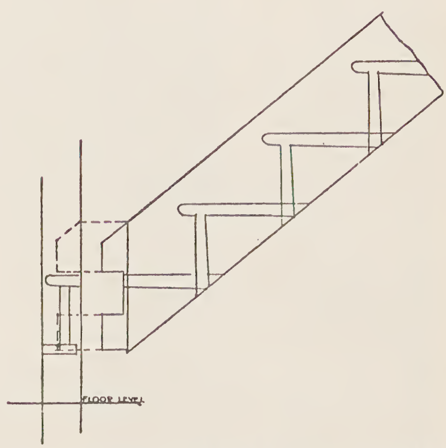


Fig. 16.—Method of fixing string to newel at bottom.

the necessary dimensions of tread and riser, and these are placed against the line parallel with the edge of the string.

The depth of the outer string must be sufficient to allow of about 3 inches above the nosing line at the top and to cover the carriages and lath

and plaster at the bottom, so that at least 14 inches will be the width required in most instances. Outer strings are frequently moulded and panelled, and made considerably heavier and wider. However the front of the bottom edge is treated, it should be extended past the face of the plaster soffit, and a bevelled groove must be cut on its inner face to receive and form a key for the plaster. In addition it is often customary to fit a cover mould in the angle formed by the plaster and the projection of the edge of the string.

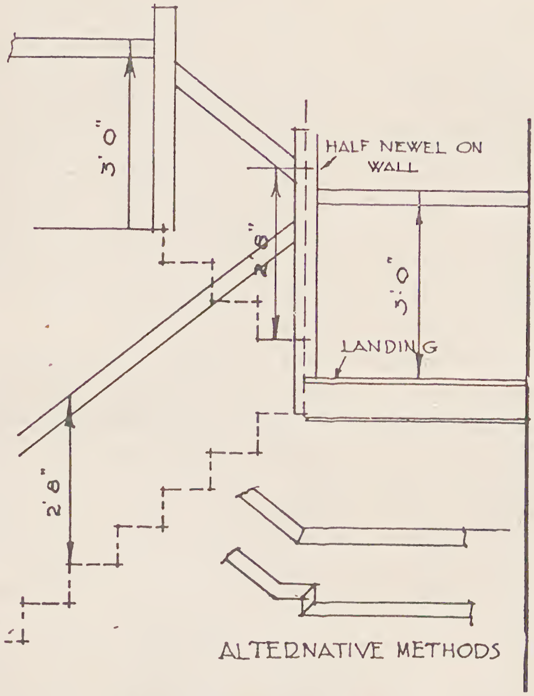


Fig. 17.—Treatment at landing.

Setting out Winders.—In order to save horizontal floor space, or space in the plan, the end of a flight is often turned at right angles to its main direction, and steps are introduced of a triangular shape which give the rise without the expenditure of space which would be required by ordinary parallel treads in the direction of the flight, and in addition the space which would be needed for a landing to be formed. These steps are known as winders, and they radiate as a rule from a newel as the centre to points on the wall string placed in the position which would otherwise be occupied by a landing. The result of this is that the tread of the winder against the wall string is wider than the width of an ordinary tread, whilst at the newel it is considerably less; and in setting out winders, an arc of a circle struck from the newel and of a radius of half the width of the flight, which is known as

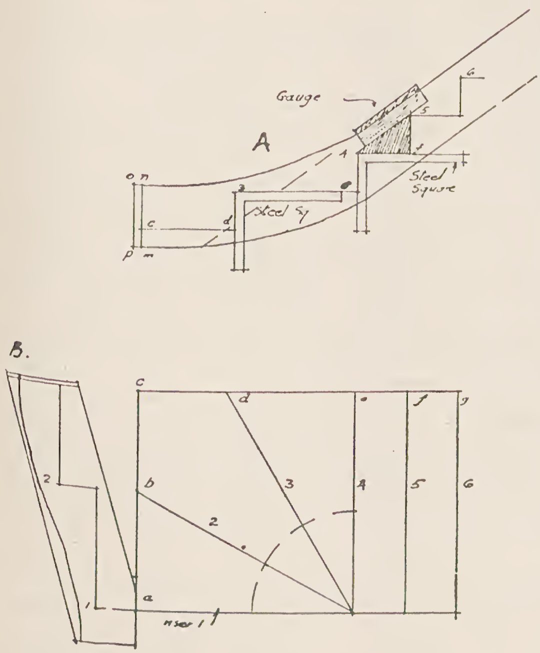


Fig. 18.—Setting out winders.

the walking line, should give a width of tread not less than those on the straight flight. This walking line is sometimes taken as being drawn 18 inches from the newel, whatever the width of the staircase, as it is conceived that that is the distance away from the newel that the feet of a person ascending or descending will tread.

As winders are sometimes constructed so that there are as many as six coming on one newel (and the height of the riser being $7\frac{1}{2}$ inches, thus $7\frac{1}{2}$ inches multiplied by 6 equals 3 feet 9 inches), they make a very considerable drop, from the top winder to the bottom winder, at the newel, and whatever the convenience of winders they cannot be regarded as a safe form of construction.

The winders are marked out on the newel by drawing the first square step on the centre line of the newel post and setting out the remaining winders equally upon the walking line. The points at which the ends of the winders will cut the wall string may then be found and marked upon a winder rod. In setting out the winders on the wall string the square steps above and below the risers will be marked out as previously described up to the rise, and the position of the face of the second winder riser will then be marked on the wall string from the winder rod. The position of the remaining winders are determined in the same way, the rise being the same as for the ordinary step, and a line joining the winder risers top to bottom will give the width of the riser treads on the wall string.

The wall string will require to be of an increased width to house the winder treads, and these joints should be either cross-tongued or dowelled and glued. It will be appreciated that the wall string, in order to follow the nosings of the winders, will have to be at a different angle from the wall string on the straight flight, and this is in fact generally formed into a curve. The curve at which the wall string will be cut out of the rough may be found by bending a lath so that it touches the nosings of the risers as drawn on the string, and drawing a parallel curve to this at the distance of the top edge of the string above the nosing, as on the straight flight. Wall strings are built up usually of 9-inch boards, and jointed at right angles in the angles formed by the two walls by being tongued and grooved.

The outer string is set out in a similar manner to the inner string, except that it runs only from newel to newel, and as the riser of the second step from the bottom is placed centrally with the newel, the first tread on the outer string will be that of the second step. And as at the top of the flight the face of the landing forms the first risers, the top tread on the outer string will be that of the second step coming down.

Risers around Cylindrical Openings.—Well holes are frequently formed at their ends without newels, but with a curve taking their place, this curve being formed in the outer string, and this has the result of doing away with the narrowest part of the winders where they would approach

the newel if there were one. This has the additional result of saving considerable work in construction of the strings and handrails which do not have to be jointed to any newels.

Where there are several risers around a cylinder the cord of the arc should be drawn, and the riser of the last rectangular tread should be so placed as to come 2 inches beyond this cord. Where a cylinder is

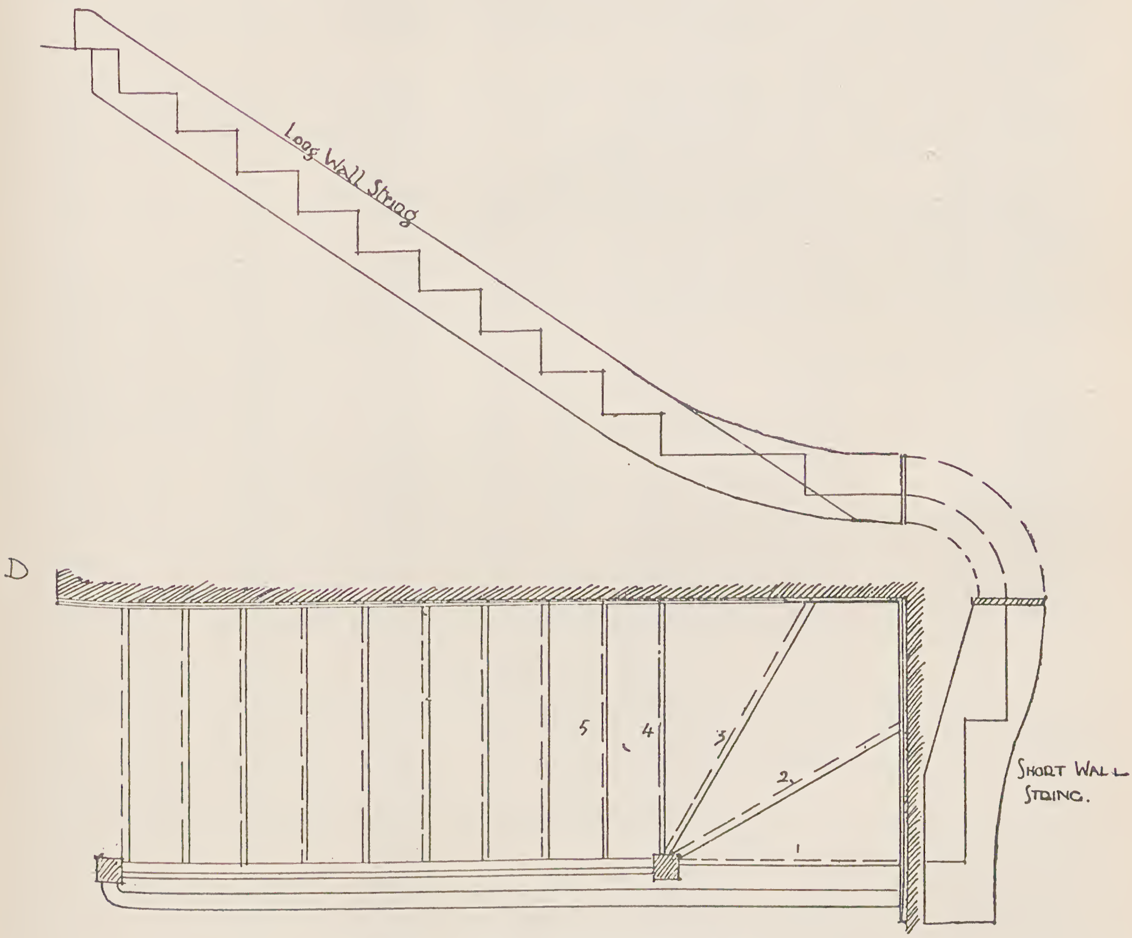


Fig. 19.—Winders and wall string developed.

placed either at the top or bottom of a flight, and there are several winders cutting on to it, the one forming the landing should be placed at least 2 inches beyond the diameter of the cylinder. The remaining winders should have their risers radiating from the centre of the cylinder at equal distances along the circumference of the cylinder. When the cylinder comes at the intersection of two flights leading from a half-space landing, or a level landing, the diameter of the cylinder should equal the width of the tread and the risers should be in the springing.

TYPES OF STAIRCASES

Whilst it is convenient to consider the construction of the parts of a staircase as if they formed a single flight—the single flight being, indeed, the basis of all types of stairs—it is rarely convenient or comfortable to run the whole stair from one floor to another in this manner, and various forms of staircases, in which the direction is altered, have been devised.
It is customary to consider the subject as divisible into *Straight Stairs* and *Turning Stairs*.

Straight Stairs are those which continue in their entire length without altering the direction of ascent, and may be formed of a single flight, or they might have one or more landings in their flight.

Turning Stairs are those in which, as has been said, the direction of flight is altered, in any of the following ways.

The simplest form of a turning stair is to introduce winders at the bottom of a straight flight, and though this is frequently done, it cannot be recommended, as it is not only inconvenient for the passage of furniture, but it makes an awkward space on which to lay the stair carpet, and as has been said, winders are dangerous, especially for children. In passing it may be noted that landings in the length of straight flights have frequently been the cause of accidents to persons when descending the stairs. In ascending they cause no such difficulty, but in descending they seem to occasion an element of surprise which is the cause of stumbling, followed by a fall down the remainder of the flight.

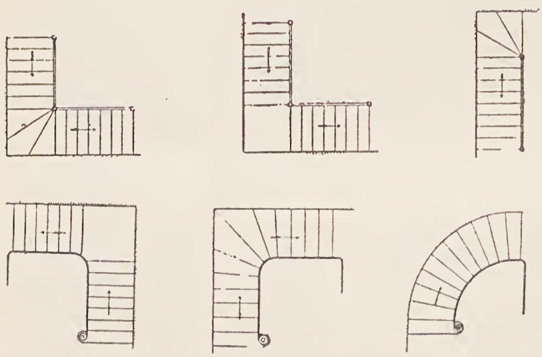


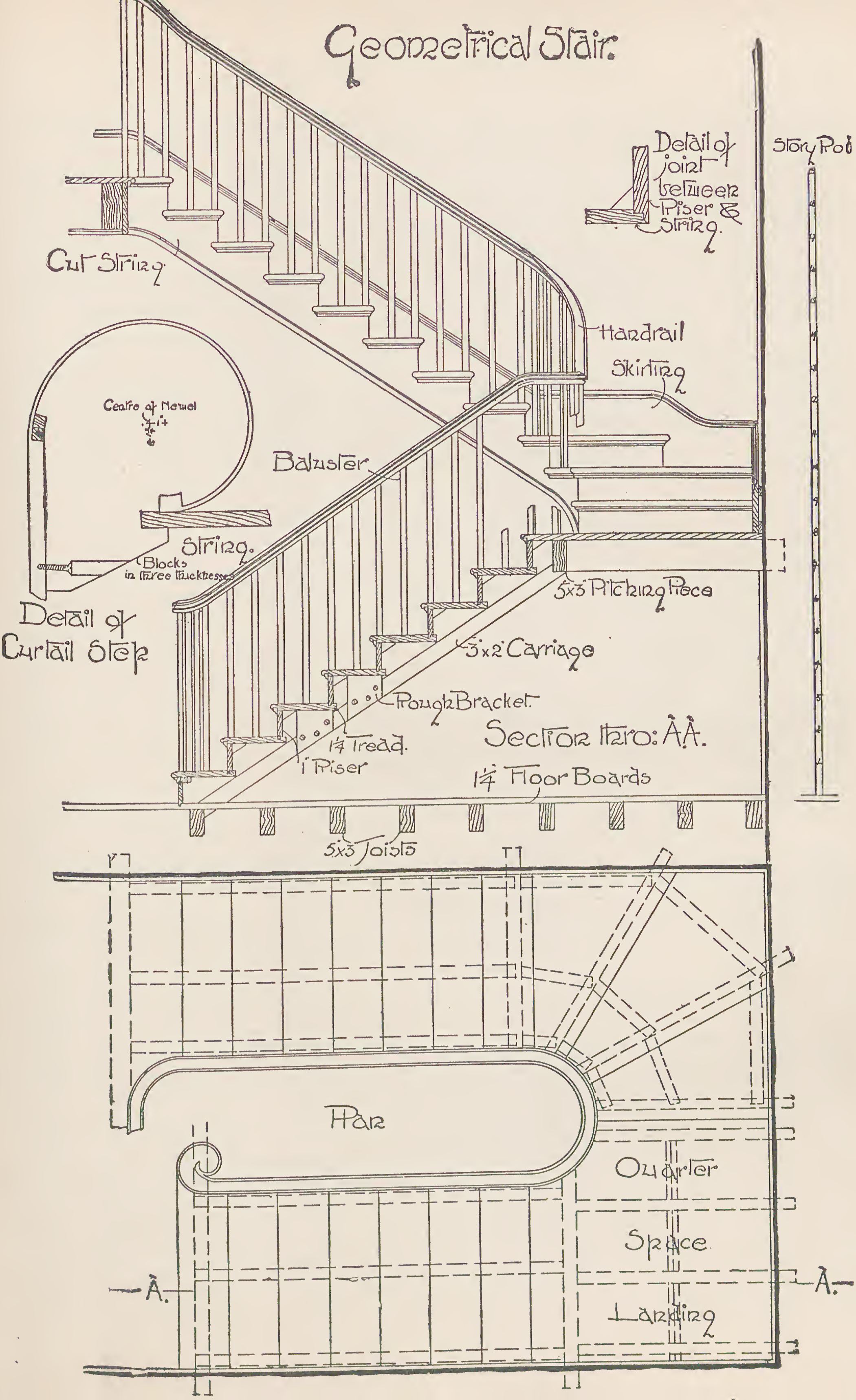
Fig. 20.—(*Top*) Quarter-turn stairs. (*Bottom*) Quarter-turn geometrical stairs.

Of *Turning Stairs*, the following are the varieties :
Quarter-turn Stairs.
Half-turn Stairs.
Three-quarter Turn Stairs.
Circular and Elliptical Stairs. (These may rightly be considered as turning stairs, but as their construction and formation are so different, they are usually treated separately.)

The foregoing varieties of turning stairs may be further subdivided into :

Newel Stairs, being those which turn at newel posts squarely ; and

Open or Geometrical Stairs, in which the strings and rails are continuous from start to finish, there being no newels except possibly at the top and


Geometrical Stair.
Detail of joint between Riser & String.
Story Rod
Cut String
Handrail
Skirting
Centre of Newel
Baluster
String.
Blocks in three thicknesses
Detail of Curtail Step
5x3 Pitching Piece
3x2 Carriage
Rough Bracket.
Section thro: A.A.
1¼ Tread.
1" Riser
1¼ Floor Boards
5x3 Joists
Hall
Quarter
Space
Landing
A.
A.

the bottom of the flight, where it is generally formed of an enlarged baluster, supporting the handrail turned into a spiral.

The Quarter-turn Newel Stair consists in its simplest form of a straight flight with winders at the bottom, causing the direction to turn at right angles. This turn may also be effected by a single landing, formed of a square, the side of which is the width of the staircase, and is known as a *Quarter-space Landing*, so that the stair consists of two flights, one leading up to, and the other up from, the quarter-space landing, and at right

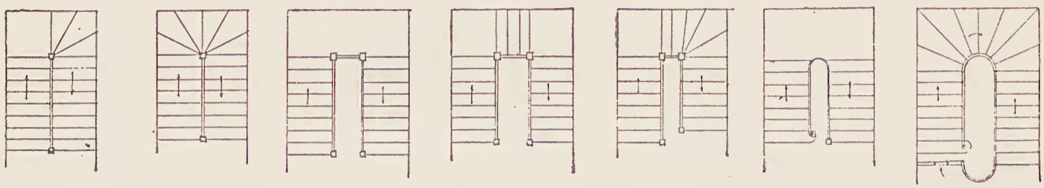


Fig. 22.—Varieties of half-turn stairs.

angles to each other. Alternatively to the last, the space occupied by the quarter-space landing may be filled in with winders (Fig. 21).

The Quarter-space Geometrical Stair is similarly one up which the ascent is changed into a direction at right angles to that at starting, and the turn may be formed by a landing or by winders as before, but without a newel; or it may be effected by turning round an arc, when the treads will be wider at the wall string than on the outer string as they radiate from the centre, *i.e.* all with the exception of the first step. This type of stair is also called a *Winding Stair*.

A further variety of stair in which the direction is turned only once, sometimes considered as quarter-turn stair, is one such as is often seen where it is desired to make the staircase an imposing feature, as in the entrance halls of public buildings. In these stairs, the bottom stairs start as a single flight, rising to a landing, from which two flights ascend in a right and left direction, at right angles to the bottom flight. These may be either newel or geometrical stairs.

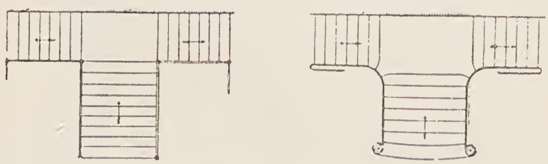


Fig. 23.—Double half-turn stairs.

Half-turn Stairs are those in which the direction of ascent is turned back opposite to that in which it begins. This turn of direction may take place by means of winders connecting the two flights ascending in opposite directions, or by a *Quarter-space Landing* of the width of one flight and winders of the width of the other flight, or by a landing extending across the width of both flights, when it is known as a *Half-space Landing*. There may also be two quarter-space landings with rectangular treads in between (Fig. 22).

The subject of half-turn stairs is further divisible into Dog-legged Stairs and Open Newelled Stairs.

Dog-legged Stairs.—These are stairs in which one outer string is placed vertically above the one below and there is no well, the one newel receiving the upgoing and downgoing hand-rail and outer strings (Fig. 24).

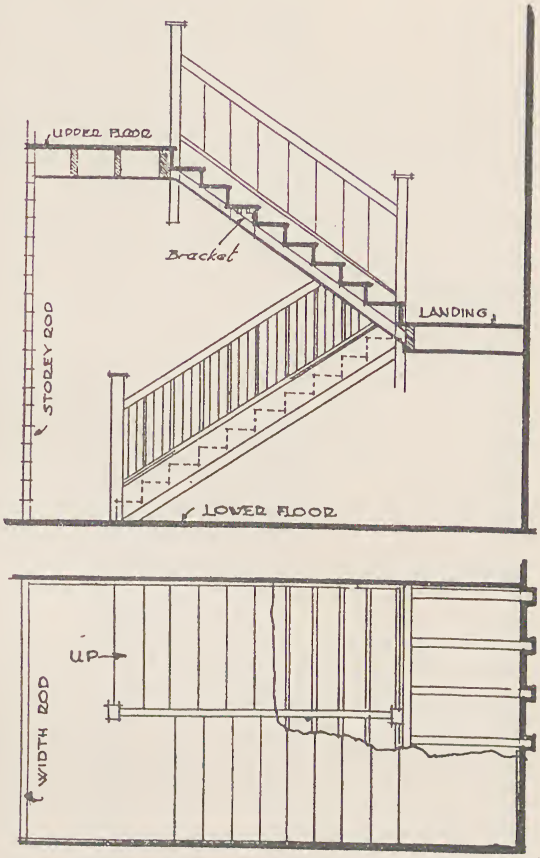


Fig. 24.—Dog-legged stair.

The only real safe method of constructing a dog-legged stair is to form a half-space landing at the junction of the two flights, for this junction formed by a quarter-spacing landing and winders necessitates three winders. If the landing is entirely replaced by winders, there will require to be six of these, so that the drop from the bottom step of the upper flight to the top step of the lower flight will be about 4 feet 9 inches, which is, as will be agreed, a height sufficient to cause a very bad accident. Stairs designed on the lines last described ought to be prohibited by law, as they are the result of poor planning; and whereas there are bye-laws concerning matters of far less importance to human life than this, it is a singular thing that this point should have been overlooked.

Another point that may be introduced here, as it has a bearing on the last-mentioned stair in particular, and on the width and turns of all stairs in general, is the fact that staircases are rarely constructed of sufficient width and affording the necessary turning space to permit of a coffin being brought down the staircase with the body of the deceased therein, it being the experience of an undertaker that there was hardly a block of flats in existence in which the coffin did not have to be lowered out of the window and brought in at the front door.

The Open-newelled Half-turn Stair is laid out in plan similarly to the last, with the difference that there is a well in between the two flights, and consequently separate newels at the tops and bottoms of the strings and handrails to each flight, and the landing, which may be, as before, a half-space landing, may be also divided into two quarter-space landings

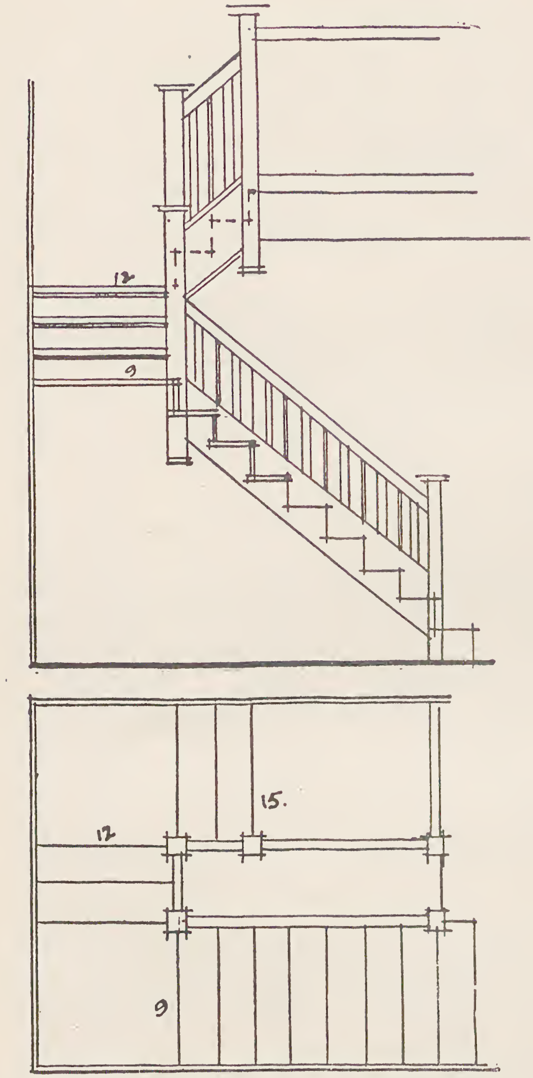


Fig. 25.—Open newel stair.

having sufficient treads between them to occupy the width of the well. This, if the well is sufficiently wide to accommodate three treads at least, probably forms the most economical, easily constructed, and most serviceable in use of all the types of staircases (Figs. 25 and 26).

The Half-turn Geometrical Stair has a continuous handrail, running round a well-hole, but the newels are replaced by semicircular or cylindrical openings, and a half-space landing divisible if required into a quarter space in one part, or four winders in the other part, or eight winders occupying the whole space of the half-space landing.

The last variety of stair may be formed at the landing at its outer space in a semicircle. That is to say, the strings, inner and outer, both form semicircles struck from the same centre, which is at a point of the inter-section of the line drawn down the centre of the well-hole with that of the lines of the two first rectangular treads produced across the well-hole.

Three-quarter-turn Stair.—This, as its name implies, is one in which the direction of ascent is turned three times. There may be some confusion between this stair and the open-newel stair, which, as explained, consists of one flight leading up to a quarter-space landing, a short space across the width of the well-hole, and a third flight in the opposite direction from the first. This last it might be reasonable to consider as a three-quarter turn stair, but in fact the person ascending a three-quarter turn stair will turn four times, that is to say, he will proceed in one direction on one landing, which will be a quarter-space, where he will turn at right angles, and then proceed to the second landing, which may be a half-space landing, on which he will turn twice at right angles, so that he ascends the last flight in the opposite direction to that

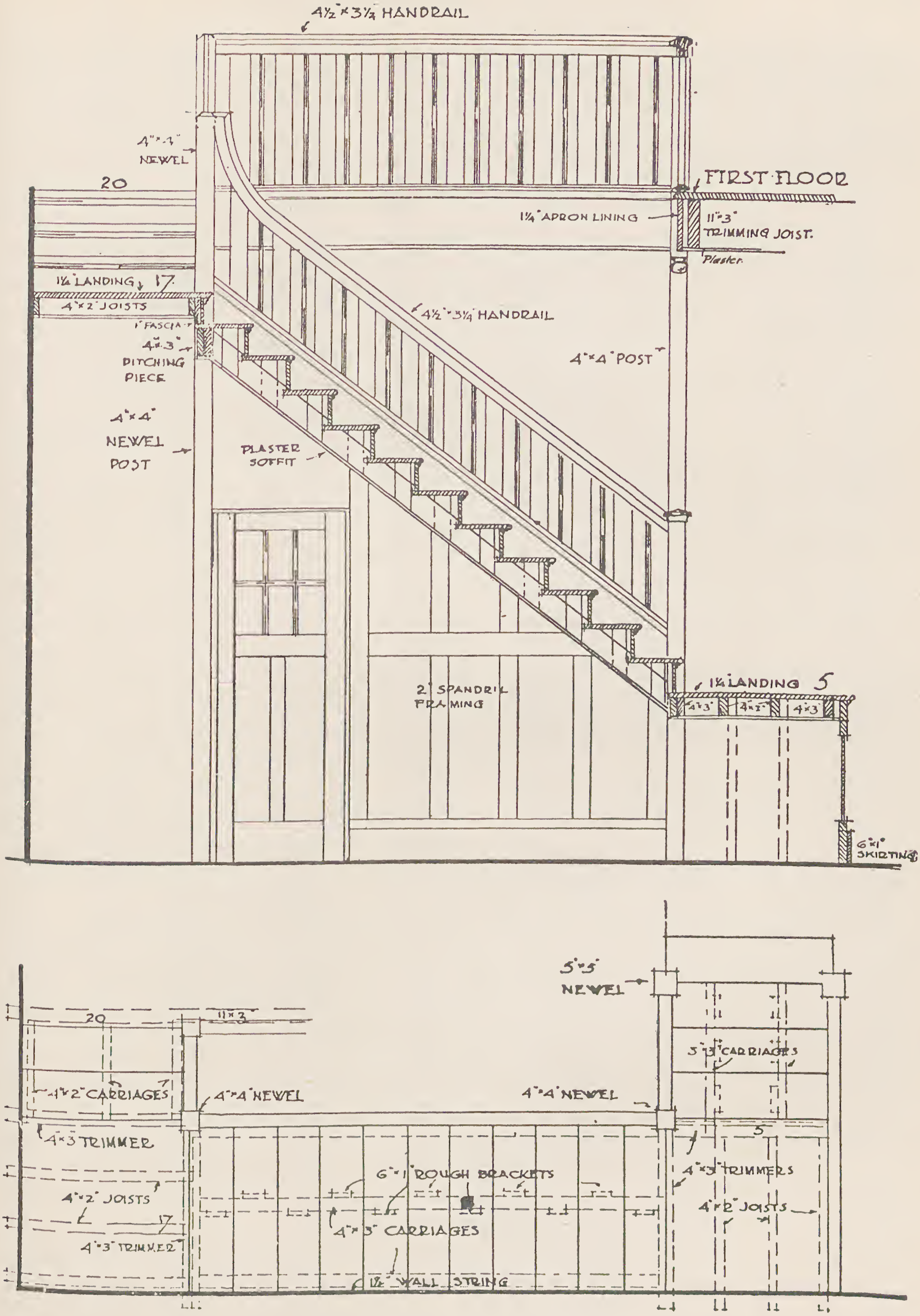


Fig. 26.—A modern open newel stair.

taken in ascending the second flight. Thus the third flight may cross over the first flight, and this introduces sometimes the difficult matter

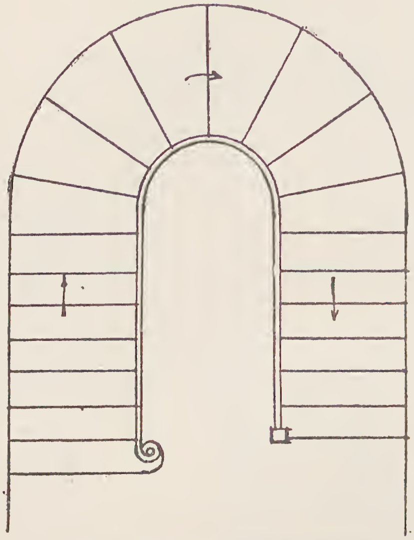


Fig. 27.—Half-turn geometrical stair.

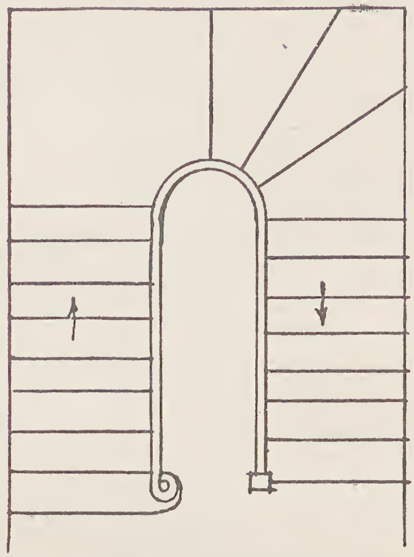


Fig. 28.—Half-turn geometrical stair.

of headroom. This will be found described at the conclusion of this description of the types of staircases.

Circular Staircases are in the nature of spirals round either a central well-hole or a central newel, and in some stairs, such as staircases in lighthouses, which are formed of stone, the central newel is built up

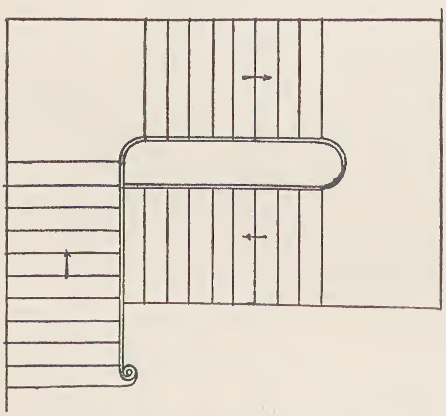


Fig. 29.—Three-quarter-turn geometrical stair.

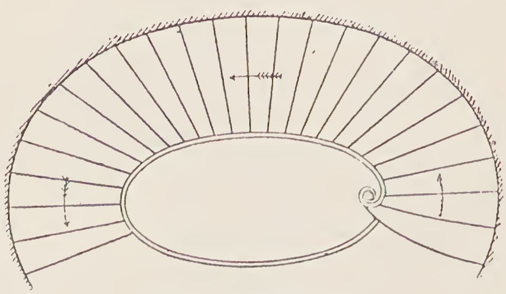


Fig. 30.—Elliptic stair.

of the circular ends of the actual stone steps. These will be found described in Chapter 12 of Volume I.

Central newel posts are also formed in wood built up; and such staircases, though more usually constructed of steel, are useful for giving access to mezzanine floors in offices and shops. The newel post is composed of four sections feather-jointed, screwed, and blocked internally,

and from this post to the outer string, which is laminated, bearers are run to carry the treads, the risers being placed down the front of the bearer. At about every sixth riser a bearer of stouter dimensions is necessary to give greater strength. On larger curves the string may be built up of narrow sections of timber placed vertically and jointed with a feathered butt joint. These boards are veneered, the veneer being glued on to their faces.

In stairs having a still wider curve, more in the nature of an ellipse than a circle, the string will be formed in the solid, and bent. But as frequent joints have to be made in the widths of timbers used in a solid string, it is doubtful if the solid string is stronger than the laminated or veneered. The joints between the separate sections are butt joints at the edge of the timber reinforced by screw dowels, such as are used in handrails, and fixing these necessitates considerable work.

It must be recognised that while the plan of the string in a circular staircase appears as a circle, it is in fact a spiral, and that not only has the timber forming the string to be bent circular, but also spirally upwards.

The strongest form of these strings is in fact the laminated string, and in this the string is bent on a drum and is built up of several thicknesses of thin wood ; the operation of bending is done under heat and steam, the wood being fastened round the drum and left until it is set, when the next board is bent and glued over it.

Other names for circular staircases are *Helical* or *Wheeling Stairs*.

Where the circular stairs are situated round an open well, the handrail is fixed on the wall side, or if it is fixed over the well-hole, there should be another one on the wall as well.

The use for circular stairs in modern house construction is not very great, as they were used in old-time houses mainly for ascending turrets which were then favoured.

Elliptic Stairs.—These are formed round an open well in the form of an ellipse, and as they require considerable space, are suitable only for very large houses or public buildings (Fig. 30).

There is also a type of elliptic staircase formed round a close newel, which may be either built up of concrete or brick, and the most useful position for the handrail on such a stair is on the wall side.

The strings for the open elliptic stair are generally formed on the outside as cut and bracketed strings, that against the wall being, of course, a close string. The wall string is laminated, as explained for circular newel stairs, the drum being an ellipse, and the open string is cut out of the solid and joined up in sections, as was described in the circular staircase.

TYPES OF STEPS

All steps, whatever their shape, consist of a tread and riser.

*A **Bull-nose Step*** is one with a rounded, quadrant, or hexagonal end, and is generally situated at the bottom of the staircase, where there may be one or two rounded bull-nose steps running round the newel, which is

situated on the second or third step. This affords an artistic finish to the bottom of the flight, and is generally used for that purpose ; or there may be a more practical reason for its employment, as for example on a landing, where an extra step is necessary at the bottom of the flight to ensure that the flight at the top should leave a certain minimum of floor space.

A Commode Step is one having a riser formed into a parabolic curve and is used for the construction of the bottom steps in the geometrical steps just described, where they will have two rounded ends, the interior newel, where there is one, and the exterior newel springing the first tread.

The shaped steps are constructed out of ribs or blocks made up.

The angle block of a bull-nose step is built up of three or more thicknesses, and notched on the outer face to receive the end of the riser which is bent round it. These blocks are glued and screwed together, and the notch or rebate for the housing of the riser face on the newel side is undercut to give security. The method of constructing this is as follows :

The distance of about 2 inches is marked from the end of the riser. The rebate on the block is placed on this mark and is then rolled round carefully on the back of the riser, and when the opposite rebate is reached its position is also marked, and a space for wedges at this end is allowed in addition. The material in between these marks is then cut away with a handsaw and chisel, a thickness of $\frac{1}{8}$ inch being left to form the veneer. Two screw holes are then bored in the ends of the blocks ; and after the face of the veneer has been well wetted with boiling water the block is glued and fixed into position by fixing the splayed rebated end into the groove cut for it in the block, and then rolled slowly round on the veneer, pressure being used until the end is reached. Wedges are then driven into the space left for this purpose, causing the veneer to be pulled up tightly, and the blocks are then screwed to the thick portions of the riser.

The construction of the commode step depends mainly upon the formation of ribs in three thicknesses, with either solid blocks at the ends or blocks built up of sections around a central square core block. The riser face is veneered on to these ribs.

A Curtail Step is also called a scroll step, and is usually the bottom end of a stair which has one or both of its ends spiral in plan and projected beyond the strings so as to stand under the spiral scroll of the handrail. It is also used as the bottom step of any geometrical stair in combination with commode steps.

The construction of the curtail step is similar to that already described as the bull-nose step, but the veneer is returned farther round the spiral, the riser is cut away in the same manner to a veneer thickness for the curved portion, but the edges of these cuts are square, and a block of about 2 inches of the original thickness is left at the end of the riser to be fixed into the circular portion of the block. This block is made up by gluing together, usually in three thicknesses of pine, so placed that the grain is reversed in the alternate thickness.

This irregular-shaped block is laid on the veneer of the riser and rolled round in the same manner as has been described for the bull-nose step, and wedges are driven in, and the block is then screwed to the solid portion of the riser.

Dancing Steps are winders that do not radiate from their common centre. One reason for their use is to lessen the danger occasioned by the vertical drop of several risers in height at a newel post.

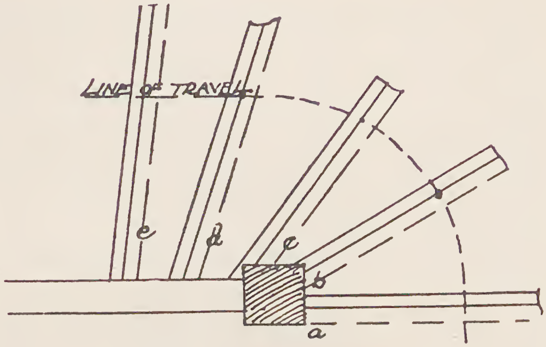


Fig. 31.—Dancing steps.

The result of this is that the width is greater at the newel than would be the case if these steps all radiated from the centre of the newel, the centres from which the risers actually radiate being advanced to points away from the last square riser. That is to say, the risers are in this case begun at several steps before the newel is reached, whereas in ordinary winders they begin at the newel.

In practice it will be found as a rule that three treads and risers cut on to the newel post, and there are two further dancing steps above these before the rectangular treads are reached. The housings for the treads and risers will come irregularly on to the newel, that for the first riser being placed centrally on to the newel, that for the second on the corner of the newel, whilst the third will be on the edge of the same face as the last, and being at angles the edges of the housings will be required to be cut at corresponding angles.

Winders.—These are steps which radiate from a central point, generally the centre of the newel post, and as has been explained, are found necessary as a means of gaining height of rise without the same expenditure of horizontal space as would be occasioned with a straight flight.

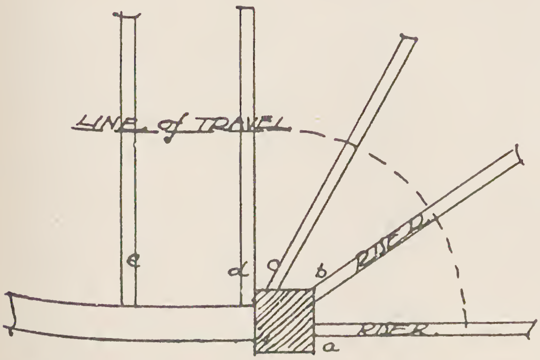


Fig. 32.—Method of setting out risers for winders.

Geometrical stairs are largely composed of winders and the other irregular-shaped step referred to above.

Winders are not recommended in ordinary dog-legged stairs, as they are particularly dangerous.

Fliers are parallel steps in a geometrical stair as distinguished from dancing steps, commode steps, and winders.

Diminished fliers are those next above and below dancing steps,

narrowed at one end in order to permit the actual width necessary to enable the centres from which the risers of the dancing steps are struck to be obtained.

CONSTRUCTION OF BALUSTERS AND HANDRAILS

The Handrail is a guard at the side of a stair run at an angle parallel to the line of the nosings and at a convenient height, generally from 2 feet 4 inches to 2 feet 6 inches, vertically above the nosing of any tread from newel to newel. This is supported by balusters, which may be of wood or metal, and housed into the underside of the handrail, or screwed thereto.

Handrails are sometimes fixed to a wall on metal brackets, when of course no balusters will be required.

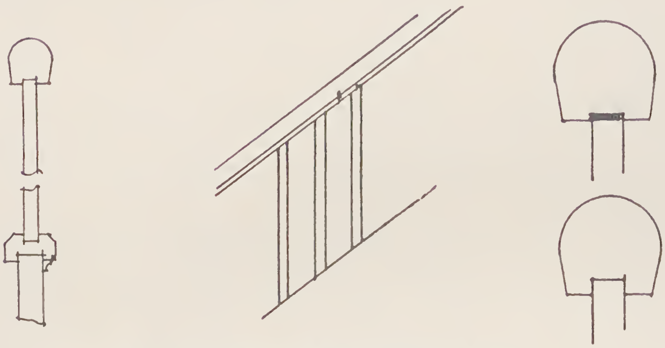


Fig. 33.—Mop-stick handrail and fixing.

So far as the most comfortable position for the height at which a handrail should be fixed, the following rule is given in Newlands' *Carpenter's and Joiner's Assistant.*

"The height of the treads from the nosing to the upper surface of the handrail should be 2 feet $7\frac{1}{2}$ inches. To this there should be added at the landings the height of half a riser."

In the opinion of the present writer this height is excessive, the theory of the matter being, that in ascending a staircase a person is in a less erect attitude than when walking along the level, and for such a position to most people—except those having very long legs, though in this event they would probably have exceptionally long arms also, so that the matter is not really affected—a height of 2 feet 6 inches to the top of the handrail is all that is required on a staircase, and of 3 feet to 3 feet 6 inches on landings.

The shape and dimensions of the handrail may vary considerably to suit the individual taste, but the essential feature, whatever the design, is that they should provide a good hold for the fingers to grasp round, and to this end no more suitable form is to be found than that known as the plain "Mop-stick Handrail." This in sectional outline is that of a horseshoe, and is usually intended when a circular handrail is called for.

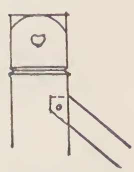


Fig. 34.—Junction of handrail and newel.

Method of Fixing Balusters.—The customary method of fixing the balusters into the handrail is to house the ends into a groove, which

is generally cut along the entire length of the underside of the handrail, though sometimes separate mortises are made for each baluster. The bottom ends of the baluster where they come down on to a closed string are tenoned into mortises cut into the capping of the string or alternatively the cap of the string may be grooved out so that the balusters may be slid into the continuous groove, the intermediate hollows being afterwards filled in.

On an open string the balusters are tenoned into mortises cut in the treads, and the nosing is mitred round to cover the joint.

Balusters in old work were elaborately turned and moulded, and though imitations of these are to be purchased in a great variety of designs from stock at the present time, yet they are machine made, and they look it. Consequently, the more simple the baluster, the better. In modern work it is now customary to use square balusters of from 1¼ inches to 2 inches, and for the sake of variety to vary them by setting them diagonally on plan alternately or to form some other pattern by alternating their positions.

HEADROOM IN STAIRS

As was mentioned in connection with the three-quarter turn stair, the subject of headroom becomes of considerable importance, as it is also in the dog-legged stair, when the floor above is carried out over the lower flight.

Headroom has also to be considered when a staircase consists of several flights, run one over the other, giving access to several floors.

The rule governing the amount of headroom which it is customary to leave is that it should be 6 feet measured from the nosing of a stair vertically. However, having in mind the furniture which has to be carried up- and down-stairs at times, the safest rule in practice is that this distance of 6 feet should be allowed measured from the nosing line, and at right angles thereto. The reason for this is that this is the actual narrowest distance through which large objects such as furniture will have to pass, and it should, of course, be understood that this is a minimum, and that a staircase so formed would usually be regarded as cramped. Where bulkheads have to be formed over stairs, additional floor space can be gained above by splaying the face of the bulkhead to conform with the 6-feet line at an angle.

In order to gain headroom for an upper flight, say, for example, that leading to rooms in an attic, the staircase may be conveniently run at an angle sympathetic, though not necessarily parallel, to the slope of the roof, but as this will not always afford sufficient headroom, dormer windows with gable roofs are cut in to supply this. The additional cost of a dormer window may be somewhat of a disadvantage, but the additional accommodation gained by using the space in the roof for rooms is a matter

worthy of consideration ; and where a comparison of cost is being made the insertion of a dormer will be far less expensive than raising the whole roof in order to get headroom.

The headroom in circular stairs is generally measured vertically from the nosing of one riser to the soffit above, and this is arrived at by the height of the rise of each step, a high rise giving more headroom than a low rise. The ordinary rise of $7\frac{1}{2}$ inches will usually be found in circular stairs to give insufficient headroom. Consequently the rise is generally made at least 8 inches.

CHAPTER 2

WATER SUPPLY AND INSIDE SANITATION

SANITATION as applied to building really means provisions for the preservation of health to the occupants of the buildings. It therefore includes a proper supply of water, removal of foul water, the disposal of surface and rain-water drainage, the provision of light within the building, both sunlight and artificial, and the admission of an adequate supply of fresh air at all times and under all conditions. This last must be carried out in conjunction with the removal of contaminated air and a satisfactory method of heating the interior of the building.

The present chapter is concerned with the water supply. The disposal of water, surface water, and rain-water was dealt with in Chapters 8 and 9 of Vol. I. The admission of daylight has been dealt with in the chapters on Carpentry and Joinery. The provision of a constant supply of fresh air is necessary so that the used air within a building may be removed (see Chapter 4 this volume). Adequate lighting is necessary to prevent injury to the eyes, the condition of which has such a very definite effect upon the health.

WATER SUPPLY

Water is supplied for use in buildings either from wells or springs, which may be deep, shallow, or artesian, or from a water company's supply conserved in reservoirs which are filled from upland waters and rivers, and by artesian wells in some instances. When the supply is from a private well, it will require to be pumped into the building by a private engine, and where supplied by a water company it is delivered by a pipe into storage tanks, from a main supply in the road.

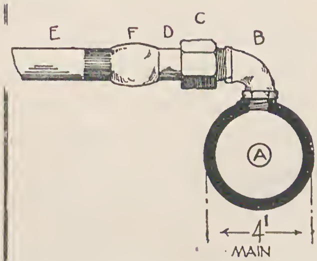


Fig. 35.—Connection to main supply.

So far as the construction of the building is concerned, the position, nature, and construction of the company's reservoirs do not concern the builder except as a matter of interest. The size, also, of the distributing mains, so that they should be of adequate dimensions to supply the district, allowing for subsequent growth, is a matter beyond his control.

Quantity of Water Required.—Whatever the source of the water supply, and whatever the system of disposal adopted, provision must be made for a minimum, and the public supply of water should be not less in volume

than 20 gallons daily per head of the population. In houses in the country where there is no public supply, the quantity of water supplied is usually reckoned as 25 gallons per person per day, with the following increases as given in Spon's *Practical Builders' Pocket Book :* for stables 16 gallons per horse, and an additional 16 gallons per carriage, and 24 gallons per motor. If water is required for the garden, this is extra. A storage cistern should be large enough to give a three days' supply.

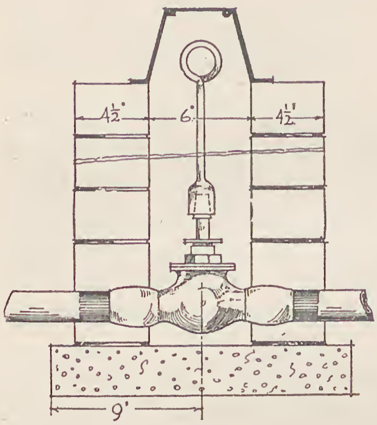


Fig. 36 —The main stop valve.

Soft and Hard Water.—Whether the supply is private or from the water company, it will vary in the degree of hardness. This hardness is caused by the absorption of lime in the water, and may be either temporary or permanent hardness. Where the hardness is in excess the water requires to be softened, and the simplest way is, of course, by boiling. This, however, is useless for drinking purposes, as it renders the water flat. A process known as Clark's process is used to soften waters temporarily hard, and a modern patent water softener known as the " Permutit " is supplied for use in domestic services.

Where water is excessively hard (for town about 5–9° of hardness is desirable) considerable trouble is caused by what is known as *furring*, which is an encrustation formed on the inside of the boiler and pipes, often to such an extent that the pipes become completely filled with the deposit. This, if it has not previously caused a crack in the pipes, must eventually result in a burst.

It will be seen, therefore, that to install a water softener is an economy.

Town Service and Connection to Mains.—A permit has to be obtained from the local Council and a fee paid before the main in the roadway may be opened up for connection to the main supply to the property, and connections may be made to the main either by the contractor or by the company's servants as arranged. The connection between the company's main and the private main is fitted either with a cock or valve, and is made by drilling the company's main through the crown. The company's main in the roadway will be about 2 inches in diameter, according to the number of houses to be supplied, and allowance is generally made for future development. The method of forming the connection is shown in Fig. 35, where A is the main, C is the cap, and D is the lining of the brass unit, which is wiped on to the lead service pipe E by the wiped joint shown at F. D is jointed to the main A by a bent ferrule shown at B. In some districts a stop-valve ferrule is used, which permits the water to be shut off directly on the main. It is not always necessary to shut off the main for this connection to be made, as by the use of a

special device the main may be drilled, tapped, and the stop valve fixed in, without disconnection.

The lead service pipe E is laid through the boundary to a brick chamber which is built up and covered at the ground level with an iron box fitted with a lid. At the bottom of this chamber a stop-valve is fitted which should have a long key reaching to the top of the chamber.

Where the house has a basement, it is advisable to have an additional stop-valve just within the external wall. The size of the service pipe within the boundary leading off from the stop-cock for an ordinary house is $\frac{3}{4}$ inch.

Storage. Cold Supply within the House.—Cold water is stored within the house, usually in a galvanised-iron tank. This is cheaper than any other kind of storage receptacle, though tanks are used constructed of such materials as one-piece porcelain fireclay, and of salt-glaze stone-

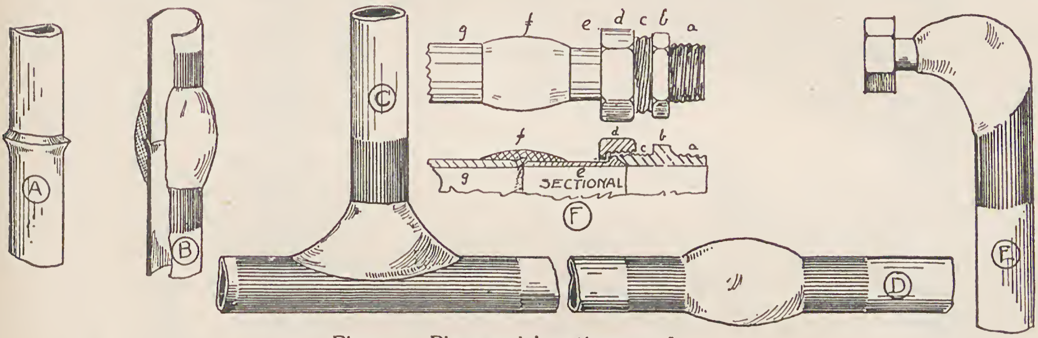


Fig. 37.—Pipes and junctions used.

A = Lip joint.
B = Wiped joint.
C = Branch joint.
D = Wiped joint in horizontal position
E = Knuckle joint.

F = Connection of lead to iron.
a = thread.
b = hexagonal shoulder.
c = thread to take cap. *d*.
d = cap
e = lining.
f = wiped joint.
g = lead pipe.

ware for use with very soft water. These last are of excessive weight and limited capacity, and there is always the possibility of breaking them.

Tin- or pewter-lined tanks are also used, and are usually found satisfactory. The amount of water to be stored depends upon the system of sewage disposal; the amount varies from 12 to 15 gallons per head for rural districts to over 50 gallons in some towns. The average taken is usually 25 gallons per head.

Cold-water storage tanks made of reinforced concrete, with the inside lined with asphalt, are becoming increasingly used.

The storage tank is situated in the attic, and should be at a height of about 3 feet above the floor, and have underneath it a lead-lined tray, and both the tank and tray must be supplied with an overflow pipe, led to weep outside an outer wall.

For protection against frost it is advisable that the tank should be boarded round with a double casing which is filled with sawdust, or other

insulating material ; and the top should be fitted with a loose cover. In this loose cover a circular hole must be cut to allow the ball-valve to rise through. It is important that the overflow waste should have no connection with any other pipe, though that from the tank may be joined to that from the tray.

The cold water is admitted to the cistern through a $\frac{3}{4}$-inch supply pipe, fitted with a ball stop-valve which closes

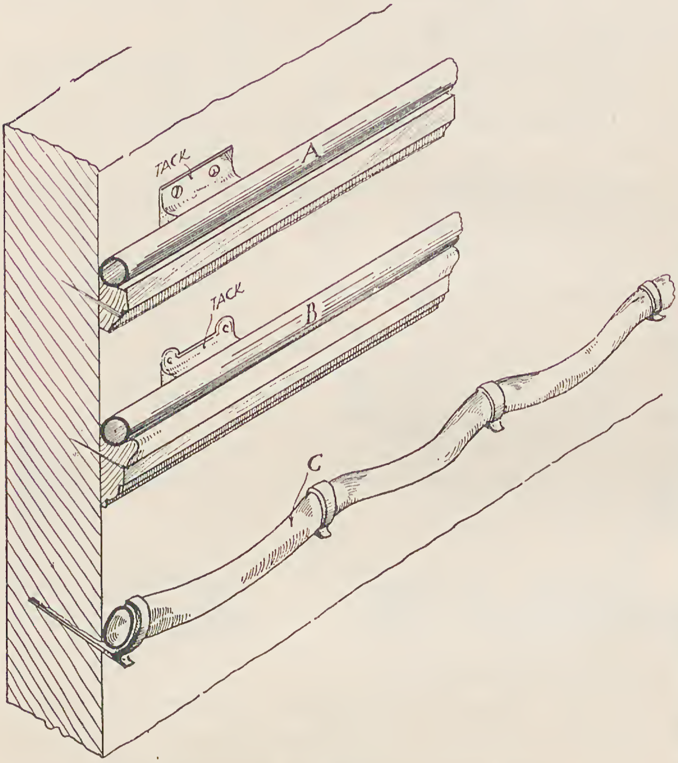


Fig. 38.—Methods of fixing horizontal pipes.

A & B = Correct on wood support. C = Faulty on pipe hooks.

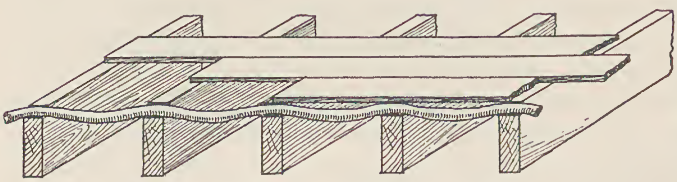


Fig. 39.—Faulty method of laying pipes in floors.

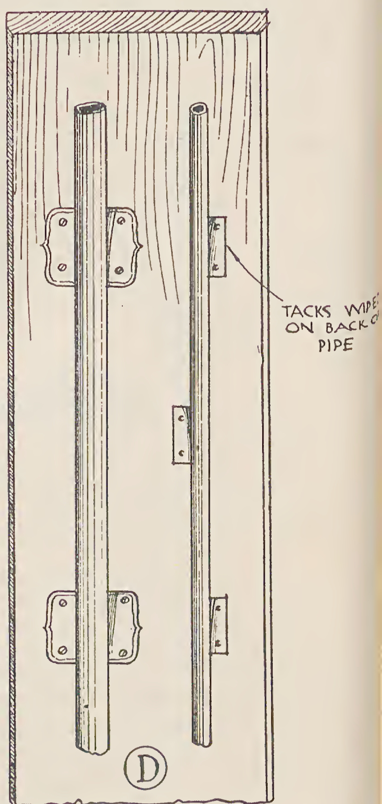


Fig. 40.—Correct method of fixing service pipes vertically.

as the water rises. When the water is drawn off and the level in the tank is lowered, the falling ball, which is attached to an arm, opens the valve and admits more water.

From this supply tank, a $\frac{1}{2}$-inch supply pipe is led to the various fittings, sink, bath, W.C., lavatory basins, and connected to these by branches.

Pipes.—The pipes which are used are formed of lead, and when properly fixed these can be used in any position. Owing to the softness and weight

of this material, they should be supported at frequent intervals. This is particularly the case when the pipes are run horizontally. Special pipe hooks are supplied for this purpose, or alternatively moulded battens may be fixed, underneath the pipe, which is better than the hooks, as unless these latter are placed so close together as to be uneconomical there is danger of the pipes sagging in between. When it is required that the pipes should be out of sight, they may be cased in, in wooden casings, but it is essential that the top of the casing should be screwed. It is a bad plan to lay a pipe across floor joists, as not only is the joist weakened by cutting the required chase, which may be a serious defect if the pipe is laid across the centre of the room, but there is also danger of the pipes sagging between the joists. It will be found advisable to run pipes along the wall wherever possible, and to choose an inner wall to lessen the danger from frost.

It is sometimes found that water has a solvent effect upon lead, and to counter this a lead-encased block tin is used. A composition iron and copper pipe is also to be obtained with a block-tin lining.

Strength of Pipes.—The standard strength of lead pipes used in the Metropolitan Water Board area is as follows :

⅜ inch diam. (internal)	5 pounds per yard run.
½ inch diam. (internal)	6 pounds per yard run.
¾ inch diam. (internal)	9 pounds per yard run.
1 inch diam. (internal)	12 pounds per yard run.
1¼ inches diam (internal)	16 pounds per yard run.

The Standing Committee on Water Regulations of the British Water Works Association, 1921, recommend the following strengths for lead pressure service pipes :

Bore.	Weight per Yard run ; in pounds.						
	⅜″	½″	¾″	1″	1¼″	1½″	2″
Light	4	5	8	11	14	18	24
Medium	5	7	12	16	21	27	33
Heavy	5½	9	16	21	28	36	48

Copper Tubes.—Copper is used increasingly for water pipes, as it has certain advantages. The copper does not corrode, has a low frictional resistance and considerable strength. Consequently, pipes of a narrower bore and lighter gauge can be used. It can be bent with ease, and is easily adapted to compression joints, which quality makes it particularly useful for hot-water supply.

The sizes and thickness of metal required for the supply or the distribution of water are as follows :

Internal diameter of pipe in inches.	Thickness of metal.	Number of threads per inch.
½	15 I.S.W.G.	20
¾	15 I.S.W.G.	20
1	14 I.S.W.G.	20
1¼	14 I.S.W.G.	20
1½	14 I.S.W.G.	20
2	13 I.S.W.G.	16

Note.—The Water Authority may permit the use of tubes of lighter gauge, with couplings of an approved type, as an alternative to the last table for screwed tubing.

Sizes and Data.—For the cold pressure service the diameter should be from ⅜-inch to 1¼-inch lead pipe. From 1¼ inches to 2 inches galvanised-iron "steam strength" with screw joints, and above 2 inches cast-iron pipes are used, with heavy socket for caulking the socket and spigot joints.

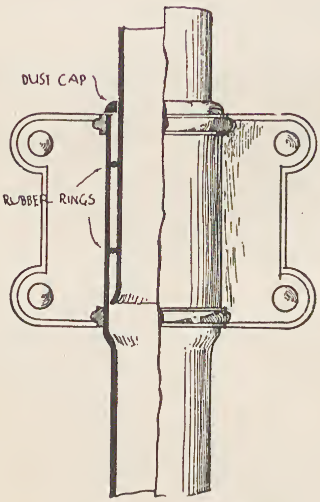


Fig. 41.—An expansion joint.

Joints on lead pipes are wiped soldered joints, and they should be made without reducing the bore.

The main supply from the stop valve to the building should be laid at least 3 feet from the surface as a protection against frost; the fittings and junctions may be of gunmetal, hard brass, or white metal of specified weight and standardised threads tested to withstand 300 pounds per sq. inch.

Valves, with the exception of ball-valves, should have a full size "water way," and in addition to the main stop-valve, considerable trouble is saved if each main branch is fitted with a separate valve. This enables minor repairs to be carried out, such as fitting a new washer to a tap, without the disconnection of the whole system.

In laying pipes they should be so arranged that drainage cocks can be fitted at fixed points, so that they can be emptied in times of frost.

Joints.—The joints in a lead pipe must of necessity be as strong as the pipes. These, where one lead pipe is joined to another in its length, are termed wiped joints, and are

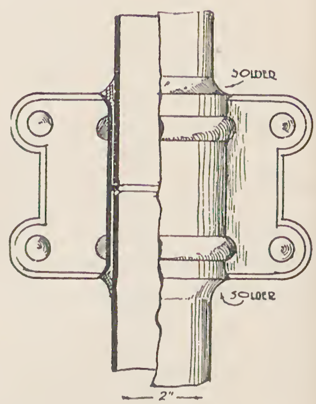


Fig. 42.—Joint on lead soil and waste pipe.

executed with solder. The operation is performed by scraping the ends of the pipes and cutting the end of one pipe to a taper, to fit into the widened end of the other pipe. Then a ring of black " soil " is painted round each pipe to prevent adhesion, and when the two pipes are fitted sogether a coating of plumber's solder is wiped round to the required thape with a tallowed moleskin pad.

Expansion Joints.—Where changes of temperature are likely to occur, as in the waste of lavatories, a special expansion joint is formed. This consists of socketed pipes fitted with cast lead ears soldered on, the socket being enlarged to give a clearance of $\frac{1}{4}$ inch round the outside of the other pipe when let into it. In the socket are two rubber rings, and the open end of the socket is closed by a cast lead ring free to slide as the pipes move.

Lead to Iron.—For jointing lead pipes to iron pipes, a thimble about 8 inches long is forced over the end of the lead pipe to stiffen it, having a flange at its lower end. This thimble is then placed on the socket on the end of the iron pipe, the joint being packed with gasket and run with lead, and the junction between the end of the thimble and the lead pipe is soldered with a wiped joint.

Lead to Earthenware.—Joints of this type occur at the outlet of a W.C. pan with the lead soil pipe. The lead work is required to be stiffened, and this is effected by jointing on a socketed brass thimble, inserted in the end of the lead soil pipe with a wiped joint on the outside. The earthenware outlet pipe is placed inside this brass thimble, and the joint is filled in with gasket and cement.

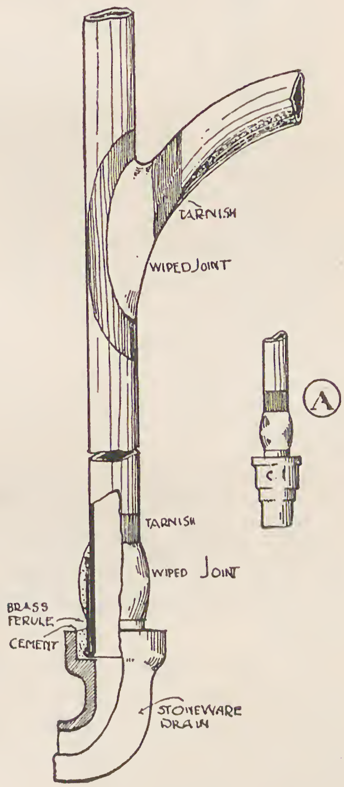


Fig. 43.—Method of jointing lead pipe to stoneware drain.
A = Lead to cast-iron drain.

Iron to Earthenware.—The earthenware drain pipe is furnished with a socket considerably larger than the end of the iron pipe, and yarn gasket is packed in the space between the two, and on top of this well-cooled neat Portland cement is rammed.

HOT-WATER SUPPLY

It is necessary to give the following few notes on the science of heat as applied to water, in order that the principles which govern the systems used in running supplies of hot water may be understood.

Theory of Heat.—Heat is conveyed in three ways :

(1) By *conduction* along and through the mass of material, so that we

say that one material is a better conductor of heat than another ; for instance, a piece of glass can be held in a flame without the person holding it experiencing any discomfort, whilst if a piece of copper were so held, the heat would soon be felt. Therefore we say that copper is a good conductor.

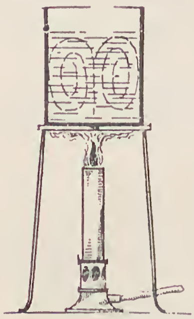


Fig. 44.—Convection currents.

(2) The second way in which heat may be conveyed is that of *radiation*. A red-hot poker, for instance, is radiant, as are the coals in an open fire, and the rays of radiation do not warm the air through which they pass.

(3) *Convection* is the third method, and is the term applied to the actual movement of the particles of a liquid produced by heat. If a glass vessel be filled with water and held over a flame, and any small particles of insoluble matter be thrown into the water, the convection currents will soon be seen rising from the bottom, passing upwards at the centre, and sinking again at the sides, as they become cooled at the surface.

The last is the method with which the hot-water system is mainly concerned, and in its simplest form the hot-water system consists of a boiler and a tank. The water heated by the boiler flows by convection into the tank.

HOT-WATER SYSTEMS

The systems most generally in use are the *Tank System*, the *Cylinder System*, and the *Combined Tank and Cylinder System*.

In the elementary side-boiler mentioned above, the top is open, but if the boiler be sealed, the heated currents will flow through a pipe rising from the top of the boiler to a hot-water tank at any desired height, and returned as it becomes cooled.

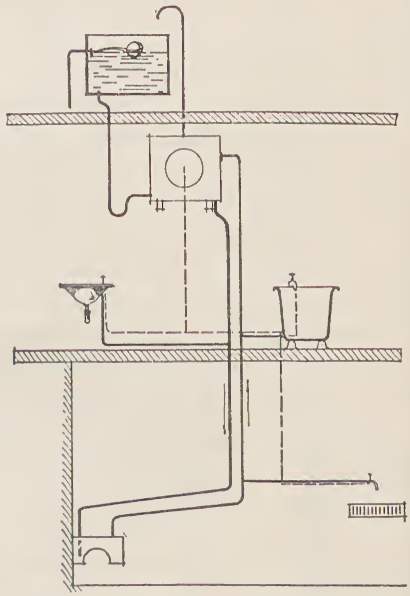


Fig 45 - An improved tank system.

In the tank system, when the fire is lighted, the convection currents ascend up the flow pipe, and as there cannot be any void in the boiler the cooler currents sink down the return pipe. Consequently, as long as heat is applied to the boiler there is a constant circulation. It is essential that the flow pipe should enter the top of the boiler, and the branch pipes for sink, bath, and lavatory are taken off the continuation of this flow pipe. The flow pipe must also enter the storage tank near the top. The return pipe leads off from the bottom of

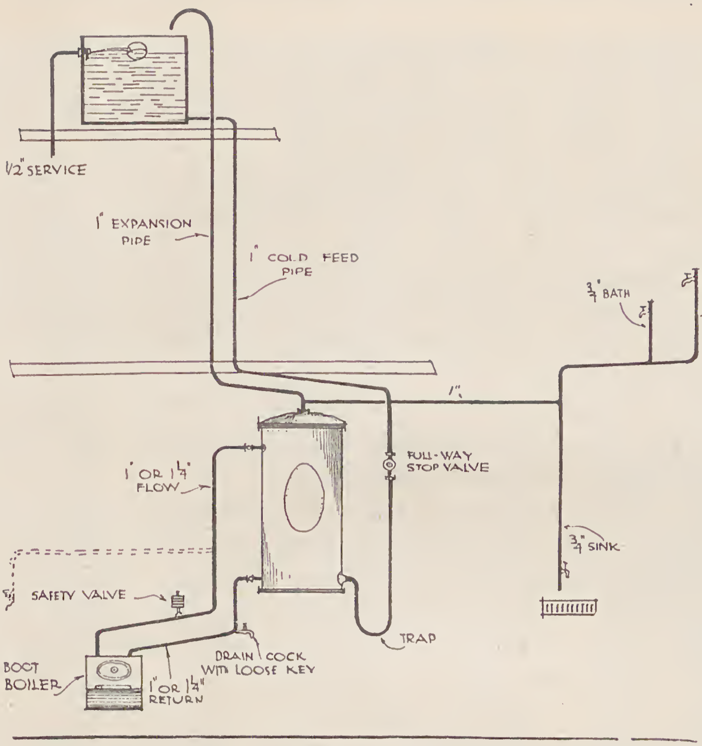


Fig. 46.—The cylinder system. Suitable for small houses.

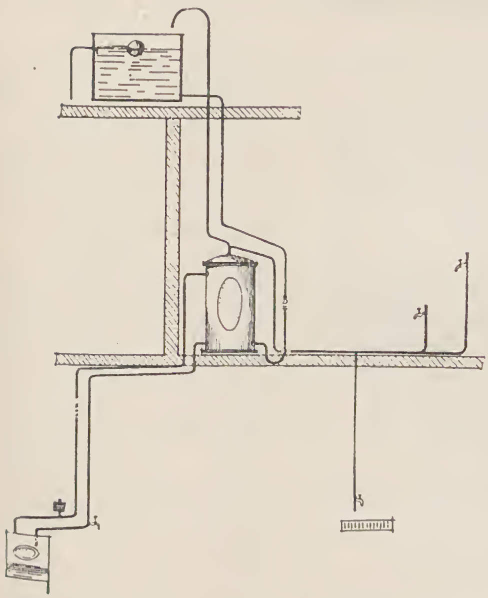


Fig. 47.—Cylinder system with cylinder on first floor.

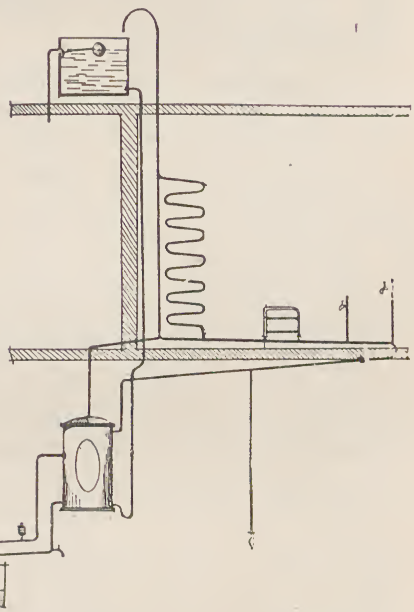


Fig. 48.—Cylinder system with secondary circulation.

the tank and enters the boiler at the side near the bottom. In such a system the hot-water tank must always be fixed above the highest fitting, which is usually the lavatory basin in the bathroom, and in consequence the hot-water tank is generally put in the roof, but this necessitates a great waste of piping, not only in the flow from the lavatory basin branch up to the tank, but also in the increased length of the return, from the tank to the boiler. It also means that when a tap is turned on, a mixture of hot and cold water is drawn off, and whilst the water in the tank may be hot, that which has been lying in the branch has been cooled. When the tap is opened, however, the hot water flows to the nearest open point, which is the tap.

As there is a cold-water supply to feed the system, there is a risk of explosion in this system, if anything should cause the ball-valve inlet to this to become stuck, as it sometimes does.

Ball Valve.—There are several types of ball valve. In one the action is horizontal, and in others the action is vertical. In all, there is a lever or valve arm, which is connected centrally to a copper ball, which rises and falls with the level of the water. At the other end of the lever arm, there is a valve plug which is pushed against or removed from the end of the inlet as the water rises or falls, and enters the tank through a water nozzle.

A good combination is supplied in which the inlet is fitted with a screw-down stop-cock, and this can be closed quickly in the event of the ball valve becoming stuck. For it will be readily seen that if the ball valve sticks, at any point, whilst the water is still rising, the water will continue to flow.

In Another Type of Tank System, which is really a modification of the last, the hot-water storage tank is placed closer to the boiler, as, for example, when it is situated in a hot cupboard in or near the bathroom.

In this system the water from the return pipe and from the cold feed pipe can mix with the hot water as previously explained. Sometimes a separate pipe is taken to the draw offs to overcome this difficulty.

The Cylinder System is the most satisfactory for the small house. In this the flow rises from the boiler to a hot-water cylinder, generally about 18 inches in diameter, fixed at a point above the boiler and as near to the boiler as convenient, so as to make the circulating pipes as short as possible, and thus minimise loss of heat. As the flow pipe enters the cylinder at its top, the hottest water will be near the crown of the cylinder. A cold feed pipe is taken from the cold tank and led by the shortest route to the join near the bottom of the cylinder. From the top of the cylinder there is an *expansion pipe*, which is really a continuation of the main draw-off pipe, and this is carried up to a point above the cold feed tank. Where a stop valve is fitted on the feed pipe it should be of the clear-way pattern, known as *Peet's Gate Valve*, to prevent risk of airlock. On this pipe the supply of hot water to the taps depends, so that it must be of a

large enough diameter to give a full supply if all the taps on the branches from it were to be opened at the same time. A trap is fitted at the bottom of the cold feed tap before it enters the bottom of the cylinder to prevent the hot water backing up to the cold feed tap when the water in the cylinder is heated throughout, and this trap must be below the bottom of the cylinder. In this system, if the cold supply is cut off, the cistern cannot be emptied.

In Another Form of the same system, the hot-water cylinder is fixed above the first floor, generally in the bathroom, but this increases the length of circulation with consequent loss of heat. It has, however, the advantage of enabling a good linen-drying cupboard to be formed in the bathroom.

Combined Tank-and-Cylinder System.—In the combined system, the supply of hot water to the highest fittings is apt to be slow. To overcome this a hot storage tank is fixed at the top of the system. This tank forms a direct head of hot water to the topmost fittings, and the boiler must be of the requisite dimensions to heat the extra water retained.

Secondary Circulation.—To overcome the defect, mentioned above, of the water in the branch pipes becoming cold, a secondary circulation of the hot water from the cylinder is arranged. This carries the water as close as possible to the points of withdrawal, in such a manner that only short lengths of pipe have to be emptied (Fig. 48).

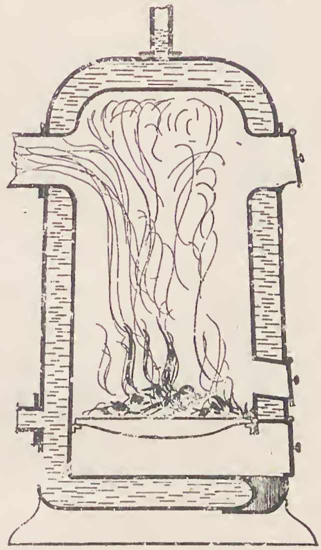


Fig. 49.—The independent solid-fuel boiler.

This secondary circulation, rising from the crown of the cylinder, is carried round to the distant fittings, and re-enters the cylinder at from 6 to 8 inches from the top. By this means it is ensured that when a tap is opened the hottest water only can be drawn from the apparatus. The expansion pipe is taken off the highest point of the system, and all piping on the circuit must be laid so that it rises gradually to this point, by which means air is prevented from being locked in any pipe, and a circulation is ensured.

Boilers.—The simplest type of boiler for domestic use is a cube which is built up on fire bricks to enable the heat to reach it underneath at the bottom.

A better form is the *Block Boiler*, which has an arched flue formed in the bottom, giving a greater area to the source of heat.

A more powerful form of boiler is that known as the *Boot Boiler*, which consists of two cubes at right angles, one horizontal and the other upright, with the flue running underneath and behind. This offers a considerably increased heating area.

NOISES IN PIPES

Water Hammer.—This is usually caused through valves on high-pressure systems which cut off the water too quickly. When the water is

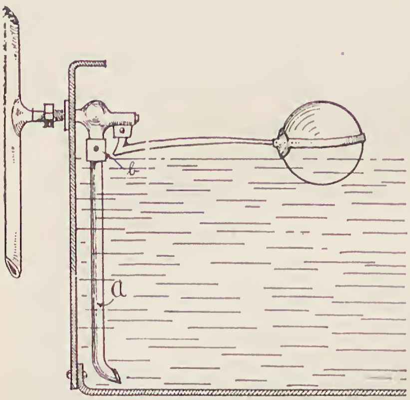


Fig. 50.—Remedy for noisy cistern.
a = silencing pipe. *b* = hole in pipe.

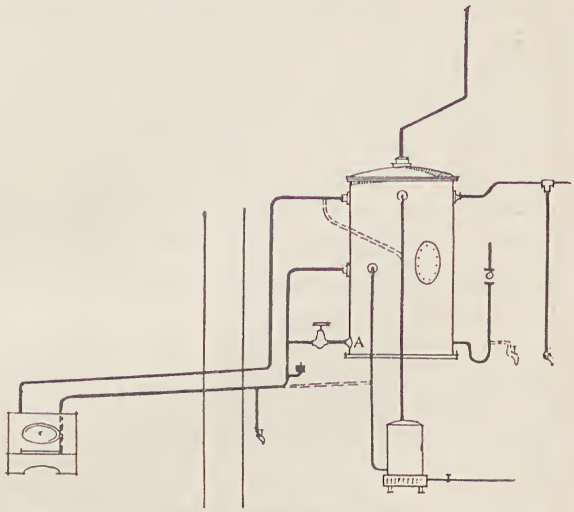


Fig. 51.—Method of remedying air trapped in boiler.
Faulty method shown by dotted lines. A = Inlet with stop cock.

turned off quickly, the force generated expands and strikes on the walls of the pipes; and although the water may be stopped by one quarter-turn of the tap, the force generated by the flowing water in the pipe cannot be so quickly cut off.

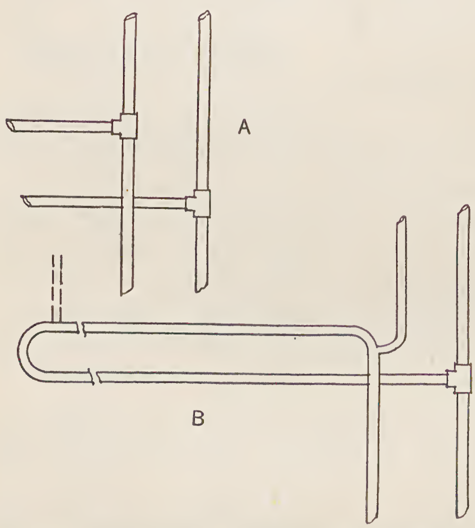


Fig. 52.—Wrong (A) and right (B) methods of running cold supply.

Chattering.—Chattering is a similar defect, and is generally caused by stiffness in the ball-valve joint, or by a loose jumper in an open stop valve. The pressure is in excess of the power of the ball valve where it ought to be well controlled by the ball.

A cure is sometimes effected in the following manner. An air vessel is fixed near the affected fitting to take up the shock on the trapped air cushion.

To lessen the noise made by the water rushing and trickling into the tank, a silencing pipe is fixed to the ball-valve inlet and taken to the bottom of the tank. But to prevent this pipe acting as a siphon, there must be a hole at its side above the water-level.

SANITARY FITTINGS

The water supply having been conducted to and stored within the building as has been described, it is next required to supply it to the various sanitary fittings, and, after use, to discharge it therefrom. These fittings in the average-sized house consist of one or more water closets, one or more baths, lavatory basins, and sinks (kitchen, scullery, pantry), and possibly a slop sink, and in the pipe junctions, inlet valves and taps, plugs, and outlets used in conjunction therewith.

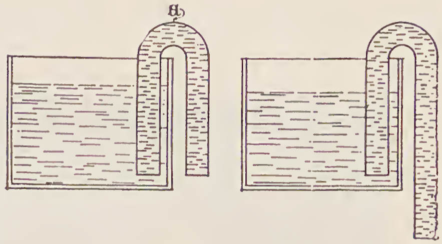


Fig. 53.—The principle of siphonage
A = hole preventing action.

Water Closet.—The supply pipe, ½ inch, to a water closet is connected to a water-waste preventing flushing cistern fixed as near as is possible vertically above the water closet.

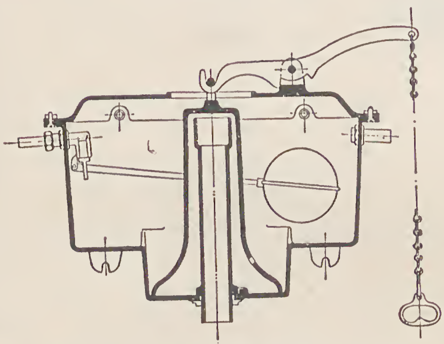


Fig. 54.—Bell-type siphonic cistern.

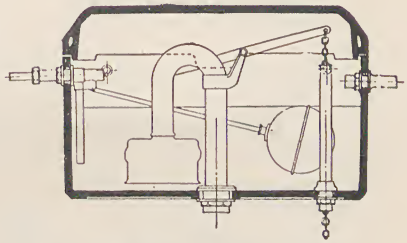


Fig. 55.—Plunger-type siphonic cistern with chain pull through cistern bottom.

This connection is formed between the lead pipe and the flushing-cistern valve by a screwed end passed through a hole in the side of the cistern, packed with bevelled washers, and secured with a back lock nut. The cistern is provided also with an overflow pipe, connection for which is made by piercing the side of the tank and fitting a brass nozzle which is wiped to a ¾-inch lead overflow. This overflow should be led away through the roof and to weep in the manner called "tell tale." That is to say, the pipe must not be connected with any other pipe or directly connected with a gutter or down spout or be fixed in any way so that it cannot be seen to be in operation. The end of this pipe should be fitted with a hinged copper flap. From

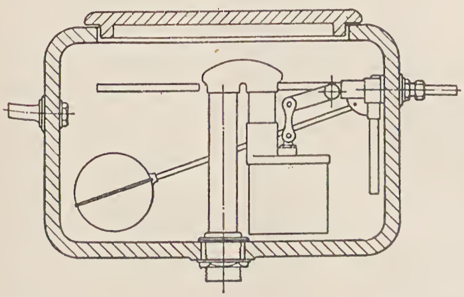
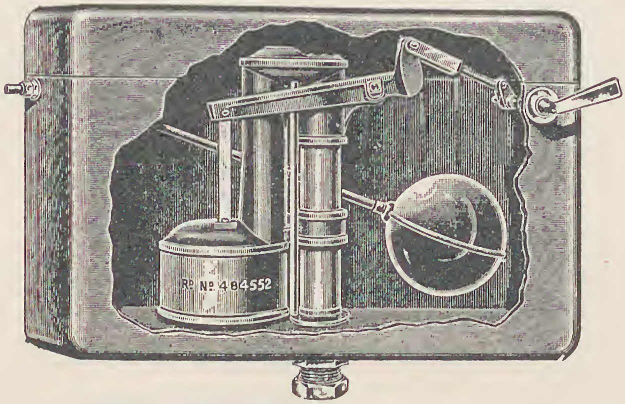


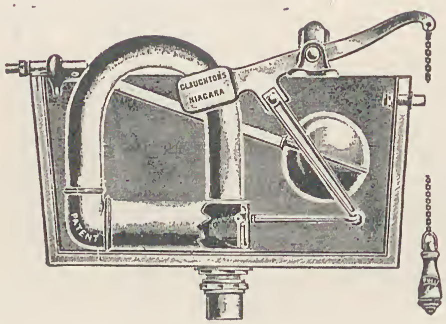
Fig. 56.—Plunger-type siphonic cistern for low-level working, operated by lever handle.

the cistern to the flushing pan the water is conducted by either a lead or brass pipe.

The operation of all types of flushing cisterns consists either of a single valve, which is opened and closed by a conical plug raised and lowered by means of the lever attached to the pendent chain and handle, or by some form of siphon. The filling of the cistern is operated by means of a copper ball valve in the same manner as that described for the main cistern, and the emptying or flushing action is operated by the lever attached to the chain pull, either operating a direct valve, or allowing air to enter the siphon tube so that water is siphoned out of the cistern.



"JAPKAP" LOW LEVEL CISTERN — METAL LINED HARDWOOD



"NIAGARA" HIGH LEVEL CISTERN

Fig. 57.—Wood cisterns, lead or copper lined.

The object of these cisterns is that they should give a good strong flush of water, but only of the necessary amount at one flushing, thereby preventing waste of water. And by their action, this flushing is controlled and made to cease more or less suddenly, so that cleanliness in the pan is maintained.

The Pan.—The essential features looked for in a W.C. pan are that the shape of the sides in particular and of the trap should be such that the possibility of fouling may be reduced. The trap in the pan should be so shaped that it contains sufficient water to serve the purpose required of it without unduly retarding the flushing action. The trap should gradually contract to the least cross-section at the bottom. Round the top of the pan there should be a flushing rim, so devised that the water is spread thereby round the whole of the inside of the pan.

The down pipe is connected to the pan by means of a cast lid connector

and rubber ring. Or, alternatively, by brass collars and brass ring and bolts, and a rubber ring. The water, after passing through this connection, is, in part, taken up by the flushing rim at the same time as the main body is discharged directly into the pan.

The outlet from the W.C. pan is connected to the lead soil pipe by a cast brass thimble, which is soldered to the lead soil pipe and fitted to the outlet on the pan with gasket and cement.

Off the lead soil pipe, and above the main trap formed in this, there must be fixed an anti-siphonage pipe. The purpose of the anti-siphonage pipe is to prevent the main trap from being siphoned out, and it is connected to a main soil ventilating stack pipe.

Types.—Of the types supplied, the "*Wash-out*" *W.C.* is not generally used. This contains a receptacle in the pan which, being dished, retains some of the water, and is consequently difficult to keep clean.

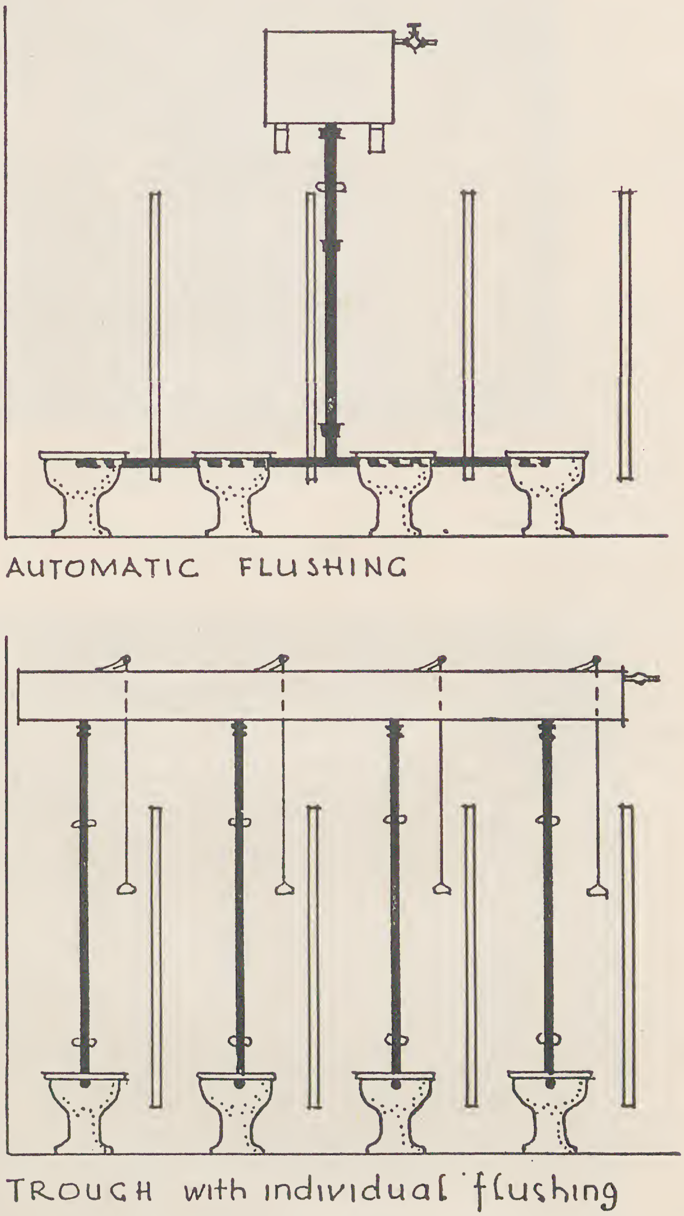


Fig. 58.—Flushing ranges of W.C.s from one cistern.

The most commonly used is that known as the "*Wash-down*" *W.C.*, in which there is a considerable quantity of water contained in the trap of the pan, and the flush consequently acts directly thereon.

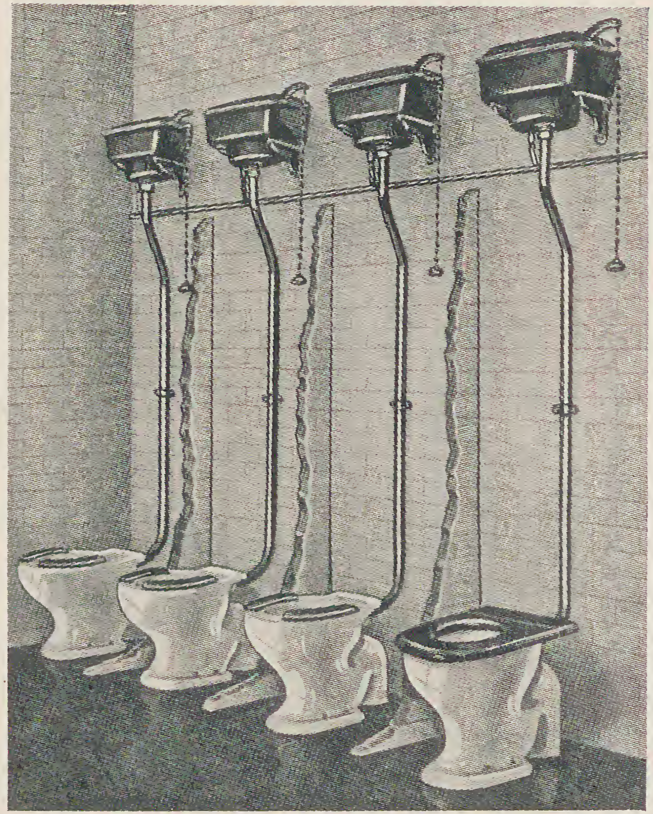


Fig. 59.—Range of closets with gravity feed to flushing cisterns.

Fig. 60.—W.C. with low-level cistern.

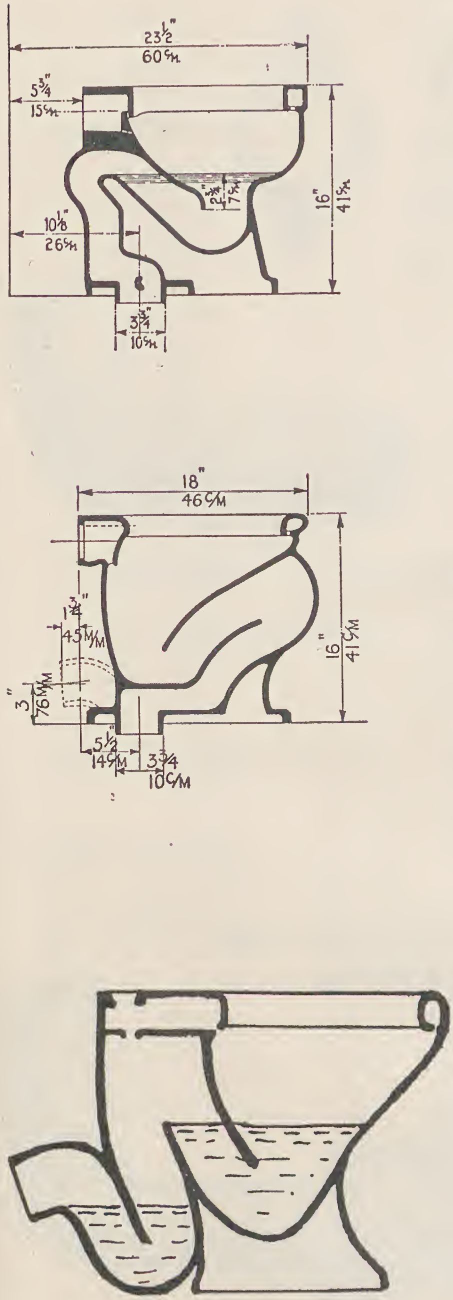


Fig. 61.—Siphonic closets—three types.
(*Top and middle*) single trap.
(*Bottom*) double trap.

Pans are also known as S or P types in accordance with the type of trap formed on them.

In some types of W.C. pan the action is siphonic, the closet pan being emptied as before by the gravitational effect of the flush, but, additionally, there is a siphonic action in the removal of the contents of the pan in the discharge being turned directly into the main trap.

THE BATH

The modern bathroom has undergone considerable changes since the days when the bath was enclosed in wood of a massive construction and generally raised on a wooden step. As this enclosure in wood, constantly wetted, was an insanitary affair, opinion swinging in the opposite direction devised baths mounted on legs, so that cleaning operations all round and underneath could be much facilitated. Again, with the swing of the pendulum, a return was made to the enclosed bath, but this now consists of either a bath cast in one solid piece, being a rectangular block with a dish in it, or, in cheaper forms, an enamel bath with an imitation marble or enamelled metal front, built into a recess or to one end of the bathroom, so that the ends and back are enclosed into tiled walls. In some of the more expensive forms of modern bath, where the floors permit, the bath is sunk

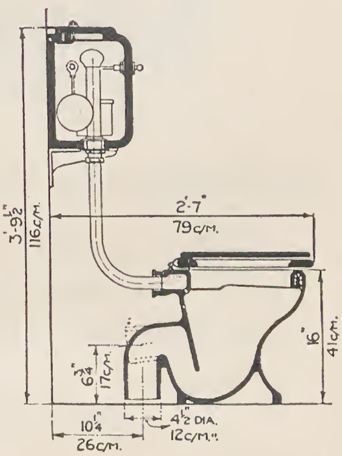


Fig. 62.—Section through low-level cistern and closet.

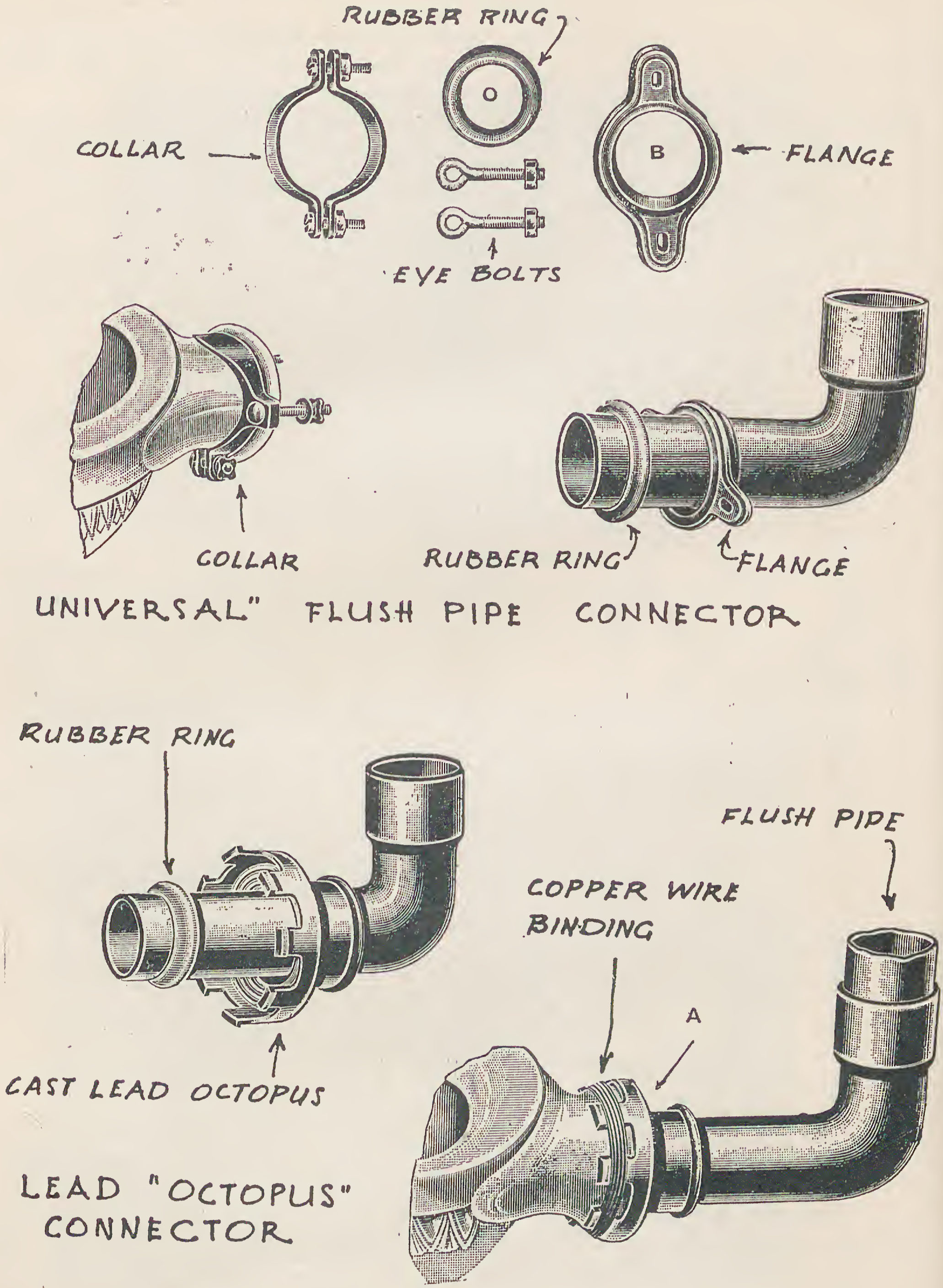


Fig. 63.—Fittings for connecting flush pipe to horn of W.C.

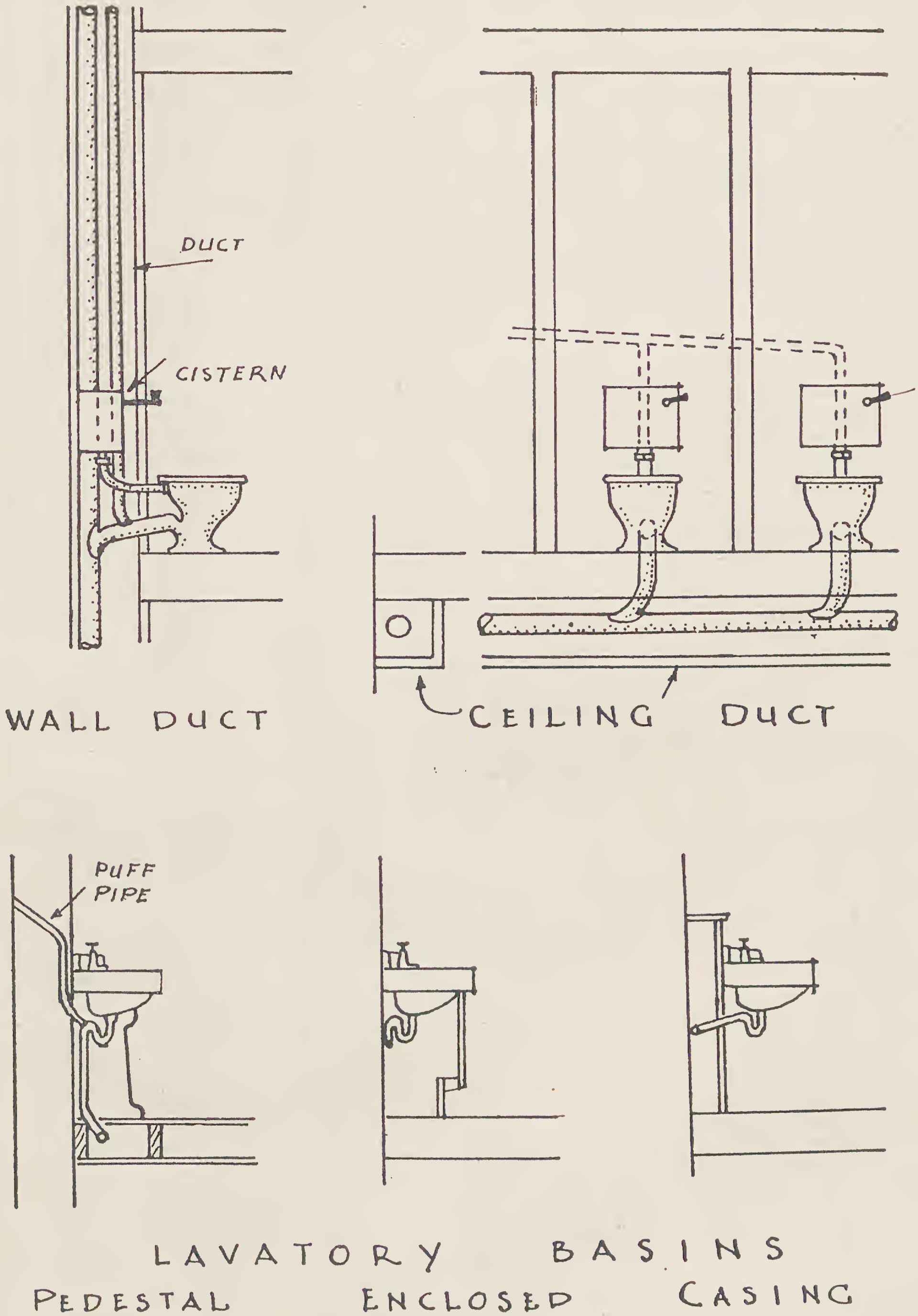


Fig. 64.—Concealment of pipes to W.C.s and lavatory basins

into the floor and set around with a hospital base skirting to throw the water out of the angle made by the floor and the bath.

Where accommodation is very limited, or in such conditions where there is no room available for a bathroom, and the kitchen or scullery has to be used for this purpose, a special form of tip-up bath has been devised, so that when not in use it can be stood on its end without disconnection.

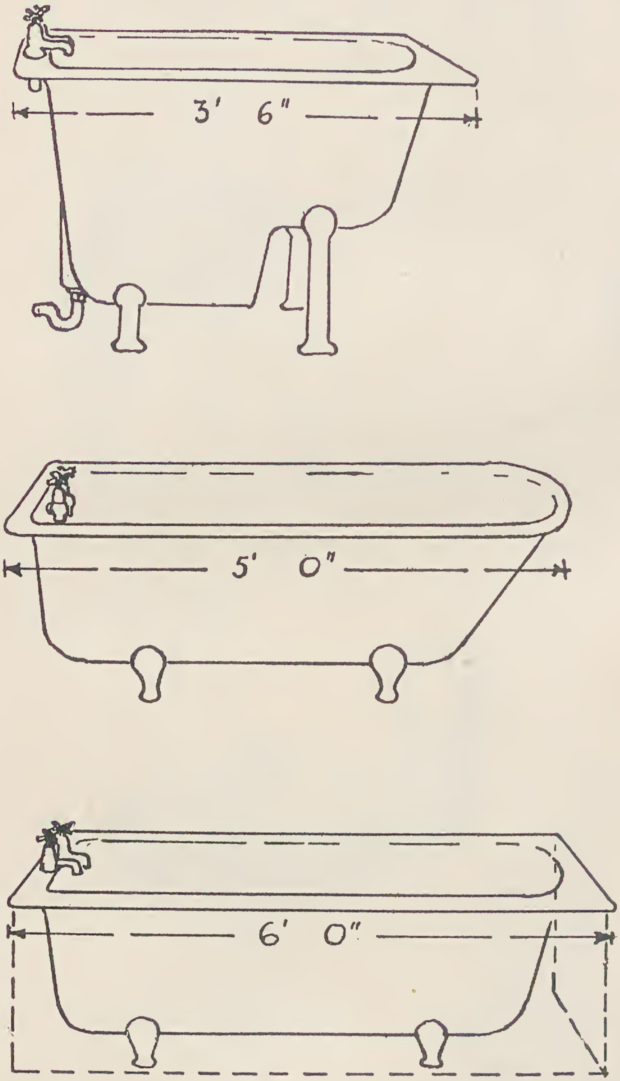


Fig. 65.—Three types of bath. The rectangular type (*bottom*) can be enclosed as indicated by broken lines.

The *length of a bath* varies from 4 feet 6 inches to 6 feet 6 inches, and the most generally used are made of cast iron with an enamel finish or a vitreous glazing. The more expensive are made of porcelain-enamelled ironware. The inlet pipes, $\frac{3}{4}$-inch lead, are connected to $\frac{3}{4}$-inch brass elbow connectors with a wiped solder joint through a hole in the bath, and are fitted with fixing plates and hexagonal shoulder, which is cast on the actual bath tap. This pipe may either pass through the side of the bath or through the roll. In the first case it is termed a *Side Entry Tap* and in the second a *Screw-down Pillar* bath tap.

Outlet Pipe.—The outlet pipe to the bath is termed the waste. This is formed of a $1\frac{3}{4}$-inch lead waste pipe which is connected to a $1\frac{3}{4}$-inch brass trap, having a seal of at least 3 inches. The brass trap is connected to the brass waste by means of a union nut, and the brass waste is screwed to the hole in the bottom of the bath by an adjustable nut and lead washer.

There must also be a $1\frac{1}{2}$-inch lead overflow from the bath, and this

is generally connected to a hole cut in the side of the bath near the top.

Special bath wastes of the pillar type in place of the ordinary plug to the outlet are fitted with slots at the sides to act as overflow outlets when the bath is filled.

A modern introduction in connection with bathroom taps and other fittings is to encase the tap with white porcelain-enamelled cast-iron casing and head. It is also customary to fit a shower in conjunction with the bath wherever possible, and this consists of a brass shower rose with a ½-inch hot and cold mixing valve with lever handle, and unions for lead pipe and ¾-inch brass pipes from valve to shower and wall mounts.

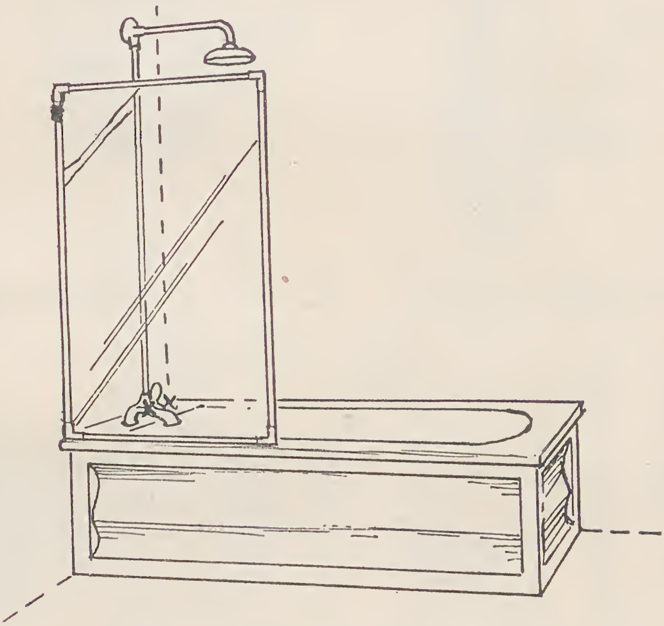


Fig. 66.—Panel bath with shower fittings.

LAVATORY BASINS

In lavatory basins used in modern work the supply pipes, usually ½-inch lead, are connected to the ½-inch service pipe by brass unions and wiped joints. The ½-inch lead pipe is connected to the pillar of the tap by means of a brass hexagonal nut and union, and a brass hexagonal nut and washer tightens the pillar to the edge of the basin. The action of the screw-down tap consists of a washer fitted to the end of a spindle, which is screwed up and down to open and close the end of the service pipe.

The type of tap known as the *Pillar Tap*, already described for the bath, is also used in lavatory basins.

The waste pipe must be trapped, and consists of a brass waste junction with a grid and a cast-brass S-trap fitted at its bottom with an access screw. Trap types are illustrated in Fig. 62.

A 1¼-inch lead puff pipe is led off from the top of the trap to prevent anti-siphonage, and an overflow must be provided also. This, in most modern lavatory basins, is formed in a channel in the back of the basin itself.

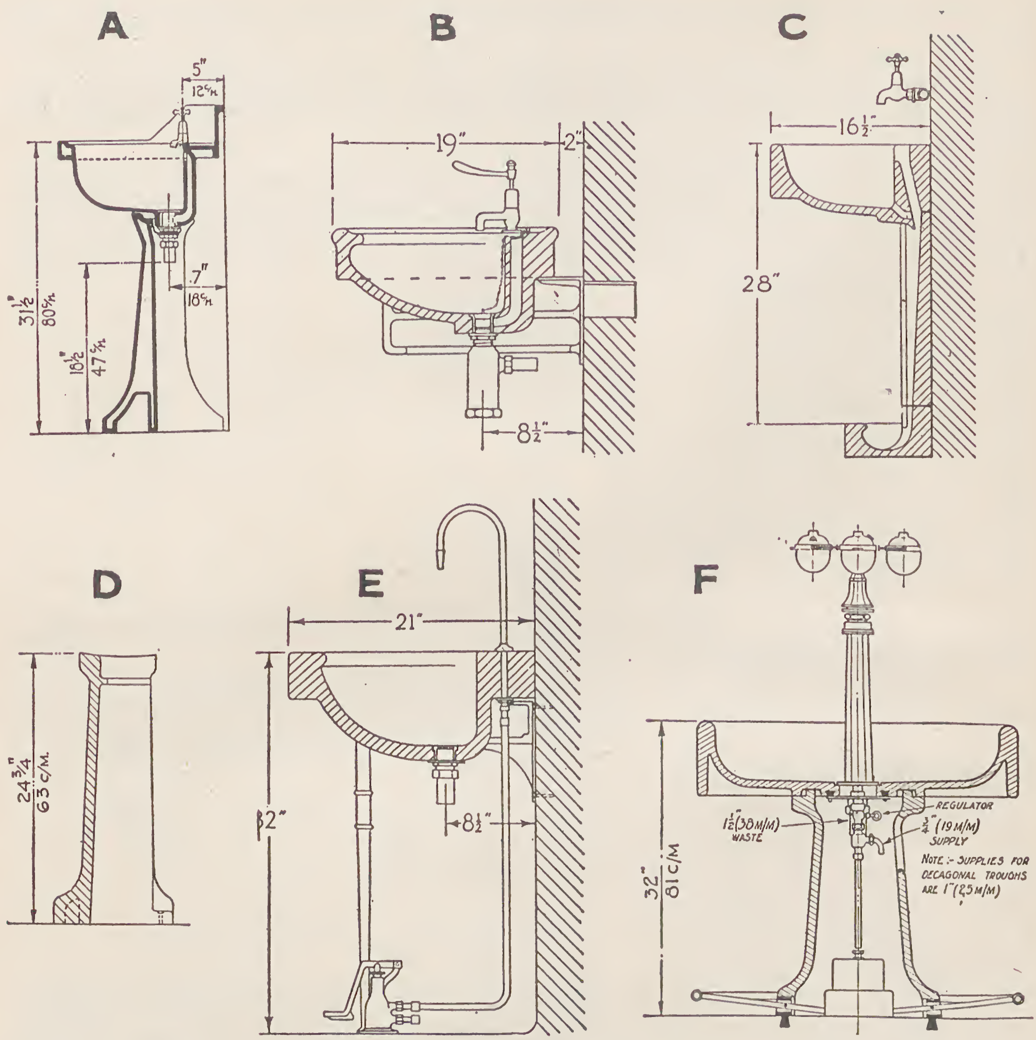


Fig. 67.—A. Lavatory basin supported on pedestal. B. Basin supported on towel-rail brackets with quarter-turn lever taps. C. Basin with open channel waste. D. Pedestal. E. Surgeon's basin with combined hot and cold nozzle, foot operated. F. Circular ablution fountain, foot operated.

SINKS

The connections to sinks consist of two brass bib taps, usually ½ inch, and a 2-inch outlet trapped as to baths and lavatories with access screw.

The outlet consists of a brass union joint wiped on the 2-inch lead waste pipe, which is trapped with a 1¾-inch seal, the trapped portion having a wiped solder joint connecting it to the waste pipe. Below this last joint there is a 1½-inch lead ventilating pipe led off to the outside, and fitted at the end with a grid or a cap having crossed wires.

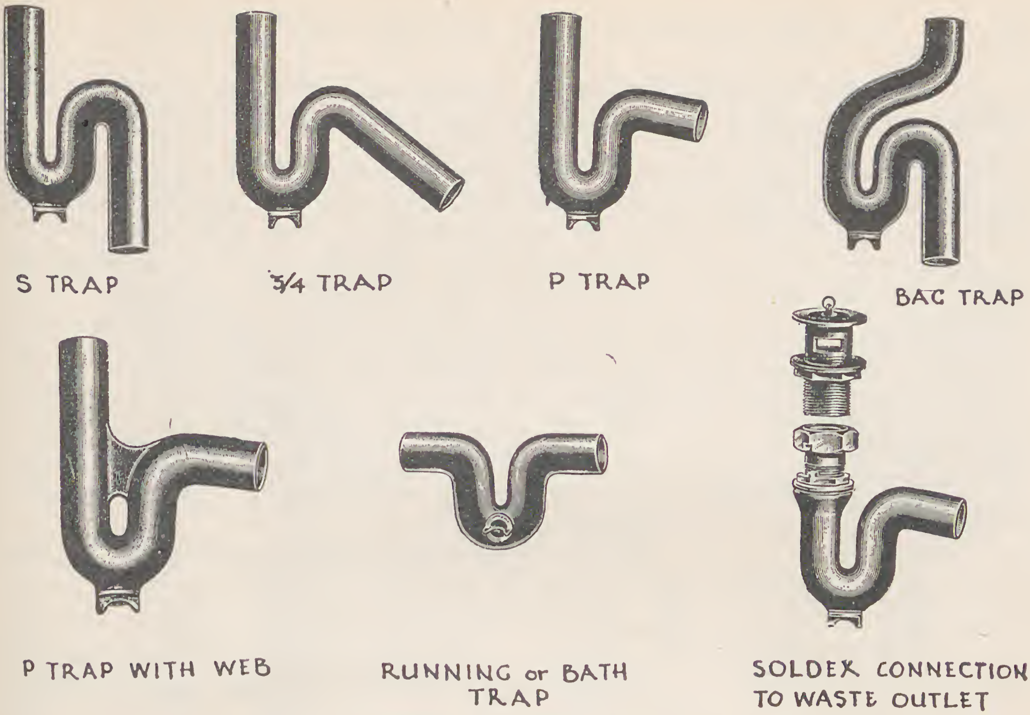
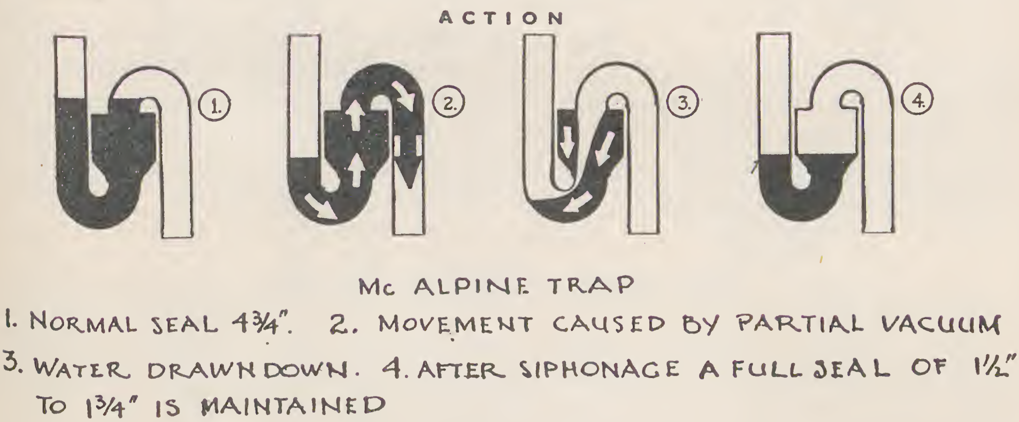


Fig. 68.—Drawn-lead traps.



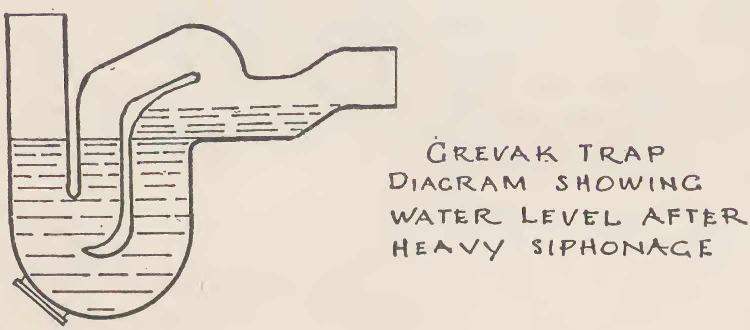


Fig. 69.—Anti-siphonage waste traps.

The overflow is either a " weir " pattern or a channel formed in the side at the waste-pipe end of the sink, and leads to the waste pipe.

Slop Sink.—The slop sink proper is a receptacle for the receipt of liquid bedroom slops, and should be fitted with a 2-gallon flushing cistern and a flush pipe in a similar way to that on a W.C. But as the W.C. is generally sufficient for this purpose, it is unusual to fit a slop sink in the ordinary-sized house. The slop sink follows the general design of the W.C., in so far as it is fitted with a flushing rim and a trapped outlet, but the outlet is also fitted with a grating to prevent its use as a W.C., and to stop the passing of soap, brushes, etc.

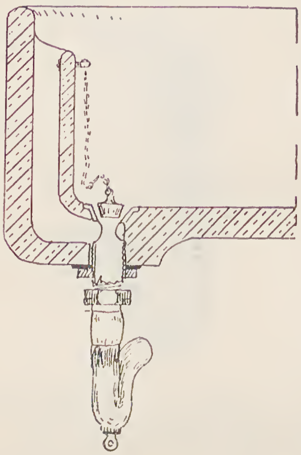


Fig. 70.—Sink with weir overflow.

Some types of slop sinks have bucket gratings hinged to lift up like the seat of a W.C., and a hardwood rim along the front edge to rest the bucket on. There should be a siphonic flushing cistern for use with the slop sink, and if there is no separate housemaid's sink, hot and cold taps and supplies may be fitted also.

The Drip Sink is not usually fitted in houses, but is a great labour-saver in such public buildings as hospitals and hotels. This fitting is not really meant for the disposal of slops, as it has no flushing rim, but is fitted with one or two taps for drawing water. The front rim is fitted with a hardwood rim, and there is usually a porcelain-enamel back about 1 foot 6 inches high pierced for the taps.

LOW-LEVEL FLUSHING CISTERN

The overhead flushing cistern has certain disadvantages, amongst which are the difficulty of obtaining a direct vertical line for the flushing pipe when a window comes immediately behind the fitting. Also in the small house, where every available space has to be put to its best use, the water closet is often fitted in under a sloping ceiling.

As there is no more sufficient reason why these should not be fitted as universally as they are in America than that they use 3 gallons of water at a flush, the water companies have stood in their way. Consequently, a definite attempt to have the bye-law altered in this matter has been undertaken.

Owing to the lack of gravitational force, the flush pipe must be of larger dimension than that used with the overhead flushing cistern. The cistern is encased in a box of either wood or porcelain, and is fitted with a ball valve actuated by a press button and lever. The connections are otherwise the same as to the overhead cistern.

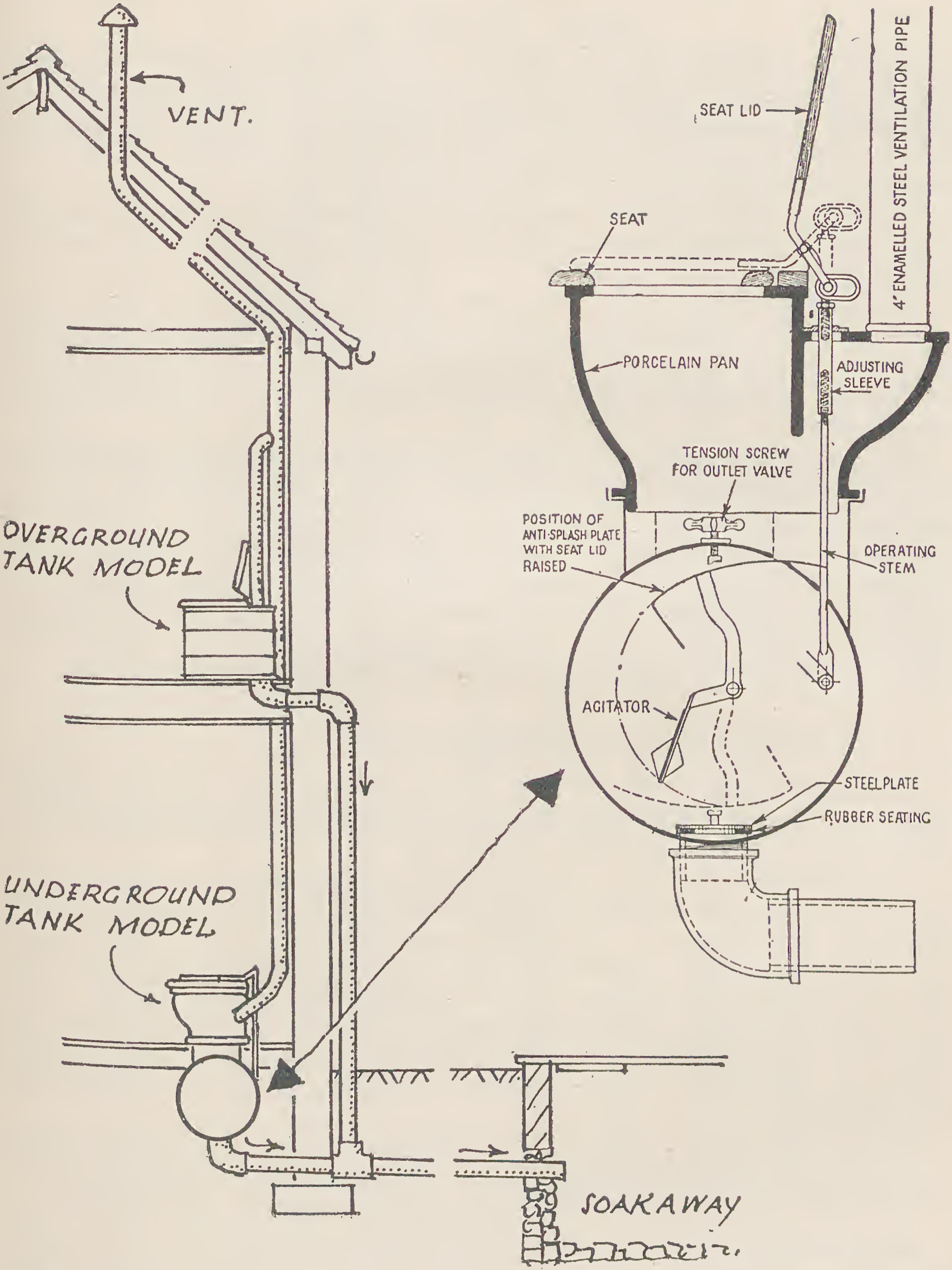


Fig. 71.—Fixed installation of Elsan underground and overground tank chemical closets, with underground soakaway.

EARTH CLOSETS, ETC.

Privies or middens, though still used, are forbidden in many bye-laws, and should be in all, as they cannot be described as anything but eminently insanitary constructions. "Middens" consist of a pit in the ground under a wooden enclosure having one or more compartments. Ashes are used as a deodorant thrown in from a bucket after use.

The great danger in their use is the contamination of the water supply when this is obtained from a well, as it is very likely to be in a district where such a closet is required.

On the other hand, quite a sanitary type of closet is to be found in a system which involves the placing of a pail under the seat and its daily removal. Ashes or dry earth are used with this, and provided the closet is situated in an outbuilding having a concrete floor, it will be found satisfactory.

The Earth Closet proper consists of a seat framework, having behind it a triangular-shaped hopper, in which dried earth is placed. This is discharged after use by means of a lever handle in the seat. Under the seat is a pail which should be emptied daily, and the front of the framing underneath the seat should be fitted with a hinged door having a turn-buckle or thumb latch. The contents of the pail, if stacked in a suitable position, become, in a period of from three to six months, completely disintegrated, and are useful as a source of humus to the garden soil.

CHEMICAL CLOSETS

Closets are now to be obtained in which a liquid chemical is used either in a pail or in conjunction with a pedestal and a sterilising tank, from which is run a drain into a soakaway.

The soakaway should be constructed at a distance of at least 15 feet from the house, and consists merely of an excavation sufficiently deep to allow of a fall of 1 in 30 to the draining pipe from the tank. However, it is unlikely that such a system would be entirely satisfactory unless the soil surrounding the soakaway were of a distinctly porous nature. The excavation should be walled round with dry walling or cobble stones, and where it is intended to use the same soakaway for bath, lavatory, and sink waste, the dimensions must be increased and a grease tap in addition will be required.

The tank is either buried in the earth or enclosed in a wooden framing above ground, and a ventilation pipe is run from this to the outside air.

The table on page 55 gives the dimensions of soakaways required.

The Portable Type of chemical closet consists of an outer ventilation chamber, a receptacle which fits inside, a ventilation pipe at the back, and a seat with a covering lid.

It is fitted up by merely cutting a hole for the ventilation pipe through the wall or roof. The chemical is placed in the pan in the proportion of

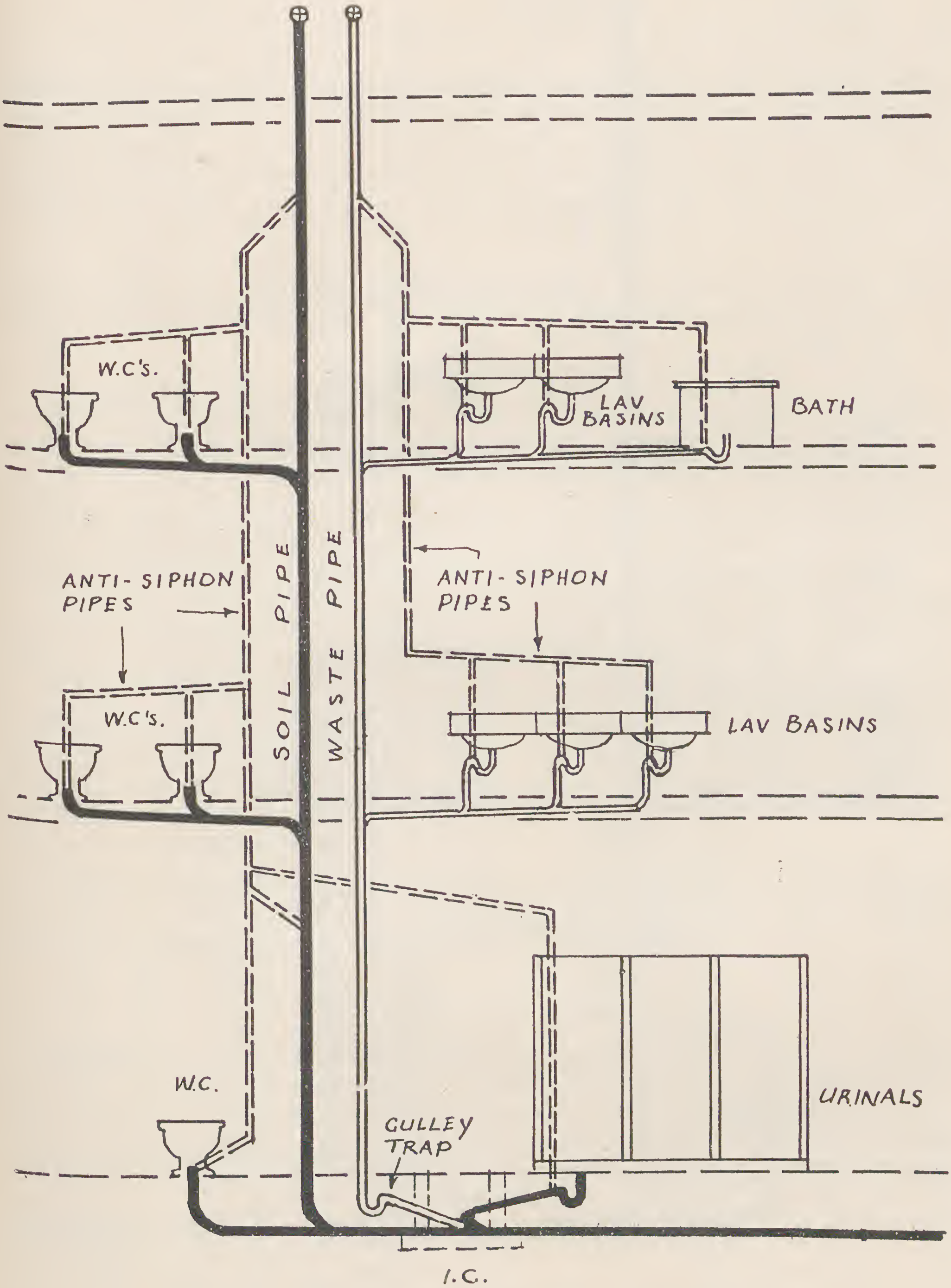


Fig. 72.—The dual or separated system of plumbing.

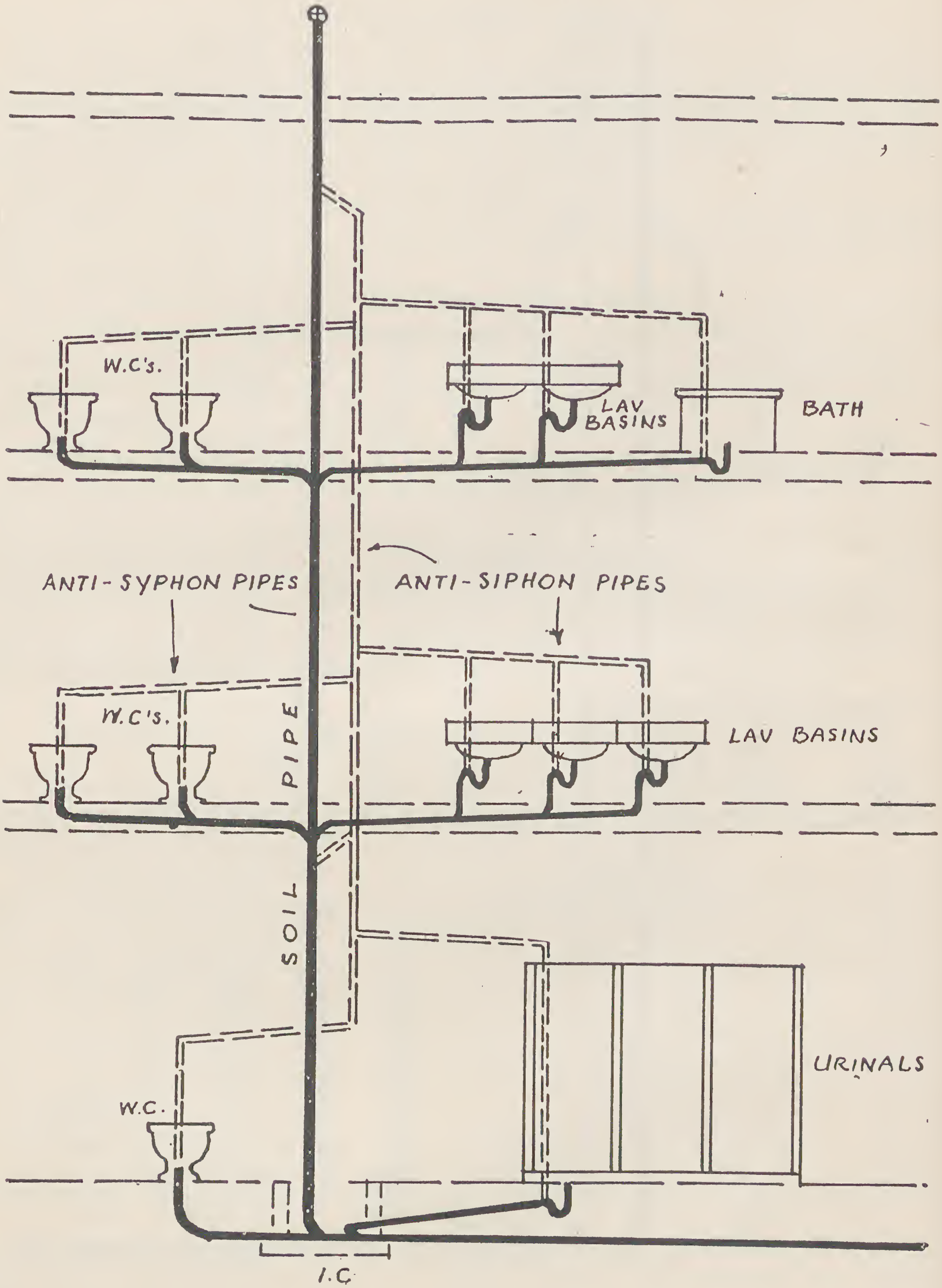


Fig. 73.—The one-pipe system of plumbing.

Model.	Total capacity of soakaway (minimum).	Suitable size for soakaway
Overground	21 gallons = 3·35 cu. feet	18 × 18 × 18 inches
Underground 32-gallon	48 gallons = 7·7 cu. feet	24 × 24 × 24 inches
Underground 60-gallon	90 gallons = 14·4 cu. feet	36 × 36 × 20 inches
Underground 100-gallon	150 gallons = 24 cu. feet	40 × 40 × 26 inches

about 1 pint to 2 gallons of water, which will be effective until the container is three-quarters full.

URINALS

The main requisite with urinals is that any area on which urine falls should be either constantly or intermittently flushed with a sufficient quantity of water. In private houses a 1-gallon water-waste-preventing flushing tank will supply this, and may be operated by a pull and lever; but in public buildings automatic systems are preferable, the discharge being about ½ gallon a minute for each urinal.

The basin urinal should be provided with a flushing rim and a projecting lip, and it is preferable if the outlet of the basin be trapped, though the outlet more usually is connected straight to the drain, having only a grid.

The slab partition urinal is usually formed of slate, and has an open half-round channel at the bottom, and the flushing is performed by a perforated pipe leading from either an intermittent automatic cistern or directly from the main supply, when it is, or ought to be, continuous. However, more often than not the flow becomes impeded, and at best this type of urinal cannot be considered as sanitary.

Urinals for Hotels are formed of white glazed fireclay, and the stalls are about 2 feet wide, the dimensions being also in fireclay, 3 feet 6 inches high, and projected from the wall about 15 inches.

DRINKING FOUNTAINS

It is required by the Home Office Regulations that drinking fountains should be provided in factories and workshops where more than 25 persons are employed. These are to be obtained in the bubbling jet pattern, which is actuated by pressure on a ring round the jet. The jet and ring are fixed over a small basin, which is fitted with an outlet. As there is no cup required, the mouth being placed above, but not touching, the jet in drinking, this form of fountain is much more sanitary than the old-fashioned metal cup and chain.

CHAPTER 3

HEATING

SPACE-HEATING is a specialist subject, the heating systems for large buildings being designed by qualified heating engineers, though for small buildings and rooms the comparatively simple heating arrangements are decided by the architect or builder.

The following systems are now in general use :

1. ***Local Heating.***—Open-fire grates burning coal, anthracite, and coke.

Stoves burning anthracite and coke.

Electric fires and convection heaters.

Gas fires and convection heaters.

2. ***Central-heating Systems.***—Solid-fuel systems fed by :

(*a*) Hand stoking.
(*b*) Gravity.
(*c*) Forced draught with thermostatic control.
(*d*) Mechanical stokers with thermostatic control.

Oil fuel systems fed by :

(*a*) Manual operation.
(*b*) Semi-automatic operation.
(*c*) Fully automatic operation.

3. ***Electric Systems.***—Electric thermal storage consists of an electric boiler and storage cylinder. Used in districts where there is a special low rate for electricity used in off-peak hours. The water is heated, usually at night, and then stored and drawn off as required.

Electric boilers. Simple to install and requiring no attention, but not economical except where very cheap current is available.

Auxiliary immersion heaters, consisting of electric heating elements cased in metal tube, fixed in hot-water tank as auxiliary heater for use when hot water is required for a short period only.

4. ***Gas Systems.***—These are used more extensively than electric systems as they are more economical :

(*a*) Natural draught.
(*b*) Forced draught.

Where special low rates for gas for central heating are in operation, it is economical, considering that fuel-storage space is not required, a small flue is sufficient, the apparatus takes up little space, and very little attention is required.

5. ***Waste-heat Systems.***—Where waste heat is available from a large steam engine, it may be used for heating and hot-water supply, and is very economical. The waste heat may be used either to give :

(*a*) Direct steam, or
(*b*) Steam used in calorifier to heat water.

6. ***Hot-air Systems.***—This is a pipeless method of central heating, and the apparatus is really a large stove usually placed in a basement under the hall, with a floor grille through which hot air rises by convection and passes through the hall and rooms of the building. In America it is widely used for heating houses, and for this purpose is economical both in first cost and running costs.

The stove can be placed in the hall, where there is no basement, and should then be fitted with an inlet grille near the floor and an outlet grille close to the ceiling. For better distribution of the warmed air, ducts may be fitted leading from the stove to the various rooms.

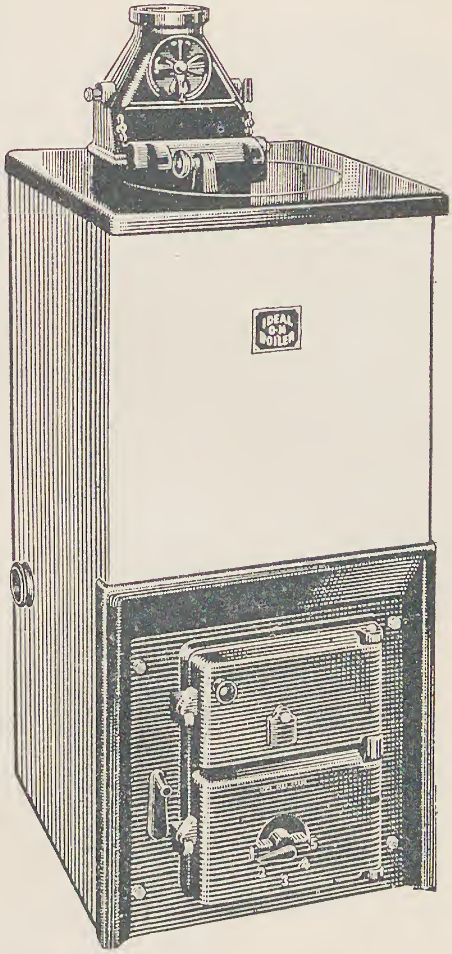


Fig. 74.—The " Ideal " O.M. magazine boiler. Approximately 60 square feet radiation with average piping. Provides hot water for domestic purposes with indirect cylinder of 20 galls. capacity. Normally, requires charging with small coke only once in 24 hours. Has a shaking grate, black vitreous enamelled doors and top plate, and cream stove-enamelled jacket.

BASIC PRINCIPLES

Heat is transmitted in three ways :

1. ***Radiation.***—Heat directly projected from the heat source is termed radiant heat. It is independent of the air and can pass through a vacuum. It travels in much the same way as light and can be reflected in any desired direction.

The rate of radiation from a hot surface is affected by :

1. The temperature difference between the hot surface and the surroundings.
2. The area of the exposed hot surface.
3. The colour and texture of the surface.

The last factor in this list is of great importance. A dark surface radiates heat better than a light one, and a light surface reflects heat

better than a dark one. Thus black is the most efficient surface for a radiator, and a very light surface such as is provided by chromium plating is the most efficient for a reflector, as in the bar type of electric fire. If a radiator is painted with aluminium paint, as is sometimes done for the sake of this paint's high resistance to heat, the radiation will be less than is obtainable from a black surface.

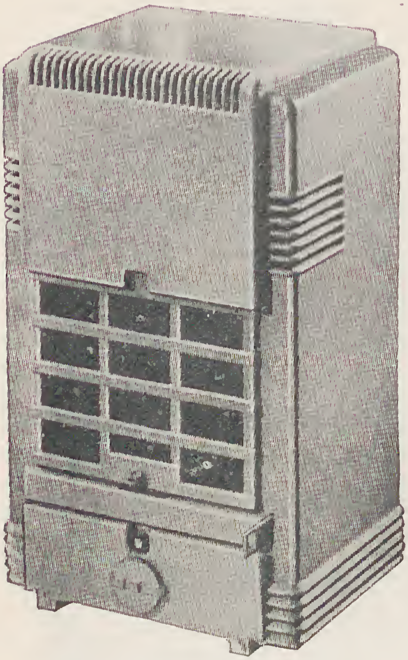


Fig. 75.—The " Otto " stove.

2. *Convection.*—Both air and water rise when heated. Air in contact with a stove is heated and consequently rises, other air takes its place and in turn rises, so that a current of air results. The same thing happens in a hot-water boiler. The heated water rises up the flow pipe, passes through the hot-water tank and back to the boiler through the return pipe, so that there is a continuous current or flow of water.

These movements of air and water when heated are called convection currents.

3. *Conduction.*—Heat travels through any material, though some materials are better conductors than others. All metals, especially copper, are good conductors, but materials of a cellular nature, such as brick, asbestos fibre, and felt, are poor conductors. A material which is a poor conductor is commonly called an insulator, meaning that it has good thermal insulation and heat can pass only very slowly through it.

Conduction is made use of in a stove, the heat passing quickly from the fire to the iron body of the stove, from whence it heats the room partly by radiation and partly by convection currents.

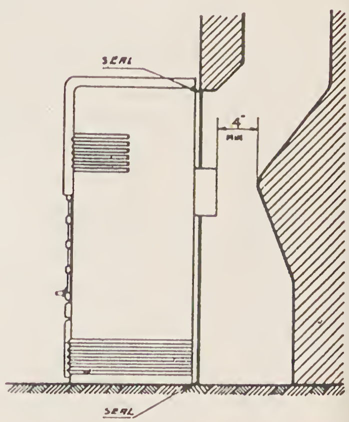


Fig. 76.—" Otto " stove fixed direct to fireplace.

Thermal Insulation is made use of in the structure of a building by which walls, floors, and ceilings reduce heat losses to a minimum in cold weather and prevent the sun's heat from penetrating too rapidly in hot weather. Hot-water circulation and draw-off pipes are often covered with insulating material to reduce heat losses. Hot-water tanks and boilers are often lagged for the same purpose. Cold-water pipes and tanks are often covered with

insulating material to protect them against low temperatures which might freeze the water. See Chapter 5 of this volume.

Insulation is of great importance in heating economy. A heating plant in a building with poor insulation of walls and ceilings may cost twice as much to run as the same plant in the same size building having good insulation. In practice, it is necessary to install a larger plant in the building with poor structural insulation, thus increasing both initial cost and running cost.

For this reason workshops and other buildings which have to be heated should have the thermal insulation brought up to approximately the standard of a house of normal construction. Buildings of corrugated sheeting must therefore be lined with thick insulation board, and the ceiling or roof insulation is even more important than the insulation of walls.

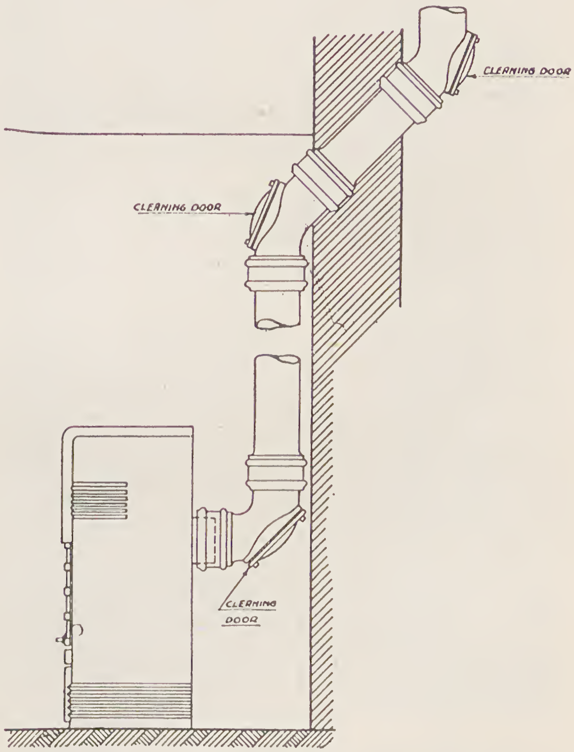


Fig. 77.—" Otto " stove with cast-iron flue pipe.

Thermostatic Control.—With heating installations which are not properly controlled there is a tendency either to over-heating or under-heating. Hand control is unsatisfactory, as it can only be done by guesswork and calls for constant attention.

Thermostatic control is entirely automatic, and should be adopted in all central-heating installations, as it saves both fuel and labour. The thermostat is an instrument which is sensitive to changes of temperature, and is arranged so that with a fall of temperature below the pre-set level more heat is released into the room, and with a rise in temperature less heat is released. A thermostat should be fitted in each room and should be set to the desired temperature.

The ordinary thermostat is sensitive only to temperature changes. The radiation thermostat is a special type which is sensitive to radiation as well as convection.

HOT-WATER HEATING

The usual forms of central heating are steam and hot-water circulation systems, and as steam in its various systems has been mostly superseded by hot water, except in some systems in which the two are used in conjunction, it is proposed to confine the following notes to central heating by hot water.

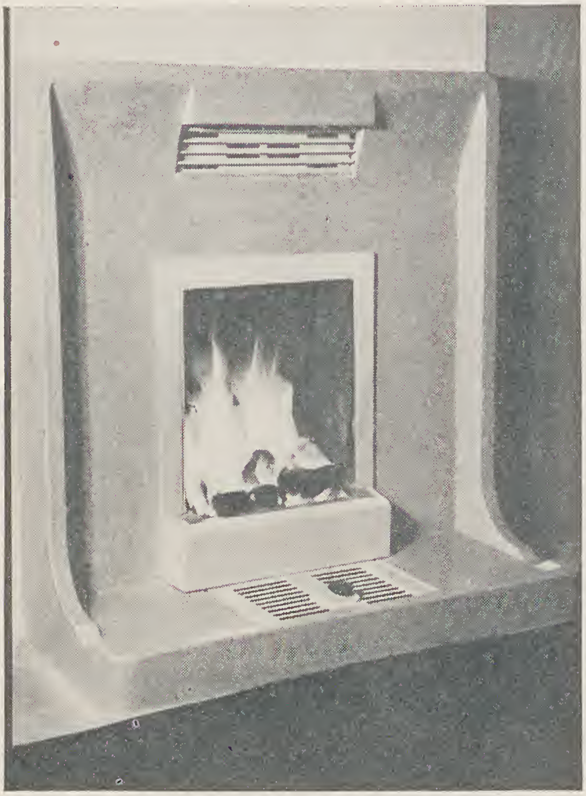


Fig. 78.—Continuous-burning open fire with under-floor air supply and air control fitted to supply convected warm air to upper rooms.

(*Courtesy The Coal Utilisation Joint Council.*)

Circulation.—When water is heated convection currents are set up, causing the heated portions to rise and the colder portions to fall and to take the place of the rising warmed water. Another characteristic of water is that when heated it expands, increasing in volume when heated to boiling-point by about one twenty-fifth of its volume at 39° Fahrenheit.

These two characteristics are the basis of the satisfactory working of any hot-water heating system, and must be borne in mind and catered for in laying out the circulating pipes of whatever system is decided upon.

The Boiler.—In choosing a boiler it is advisable that the advice of the specialist should be taken, as not only is there a very great variety of boilers to choose from, but also the boiler must be of the proper capacity to supply the system. The position in which the boiler is to be situated must also be decided, with regard, not only to the convenience of the occupants as to space and location, but also having in mind the needs of the system and its most effective work in the heating operation.

There is also to be considered whether the system is to be direct or indirect, and whether the hot-water system for domestic purposes and the hot-water heating system are to be separate or combined.

All these points determine the size and to a great extent the type of boiler.

Location of Boiler.—The combined effect of the introduction of gas and electricity at the same time as the growing popularity of central heating by hot-water systems has to a great extent displaced the old-fashioned kitchen range, with the result that the space previously occupied by the kitchen range is now used for the boiler and the cooking range, whether gas or electricity. This makes a convenient recess, and it should be remembered that by whatever means, concrete, flat or steel plate, the opening to the old flue is closed, some form of vent must be pierced in it to take the fumes from the gas and the smell of the cooking. This may be

Fig. 79.—Continuous-burning " open-close " stove, showing sliding doors partially opened. (*Courtesy The Coal Utilisation Joint Council.*)

either a gap at one side or a hit-and-miss ventilator, the latter being preferable, as it can be closed when the cooking stove is not in operation, and so prevent any tendency towards downdraught.

The boiler may be fixed in the kitchen, scullery, or any other position affording suitable flue connection, such as in the hall or even a living-room. The customary position is, as stated, in the kitchen. A typical boiler is made up of four panels, each comprising a series of small vertical water-ways united at the top and bottom, where the panels are joined together by hollow headers, thus forming one common waterway. Thus the fire and ash-pit are enclosed within a water jacket, the exterior walls of which are fully exposed to the fire. Rapid heating is also facilitated by

reason of the small volume of water in the boiler, due to the restricted area of the waterways. The fire being thus isolated, it is possible to set this boiler on a wooden floor.

There is a series of dampers, and by care in the use of these the draught may be controlled and the fire maintained for several hours without attention. A loose pan is fitted under the ash-pit for the removal of

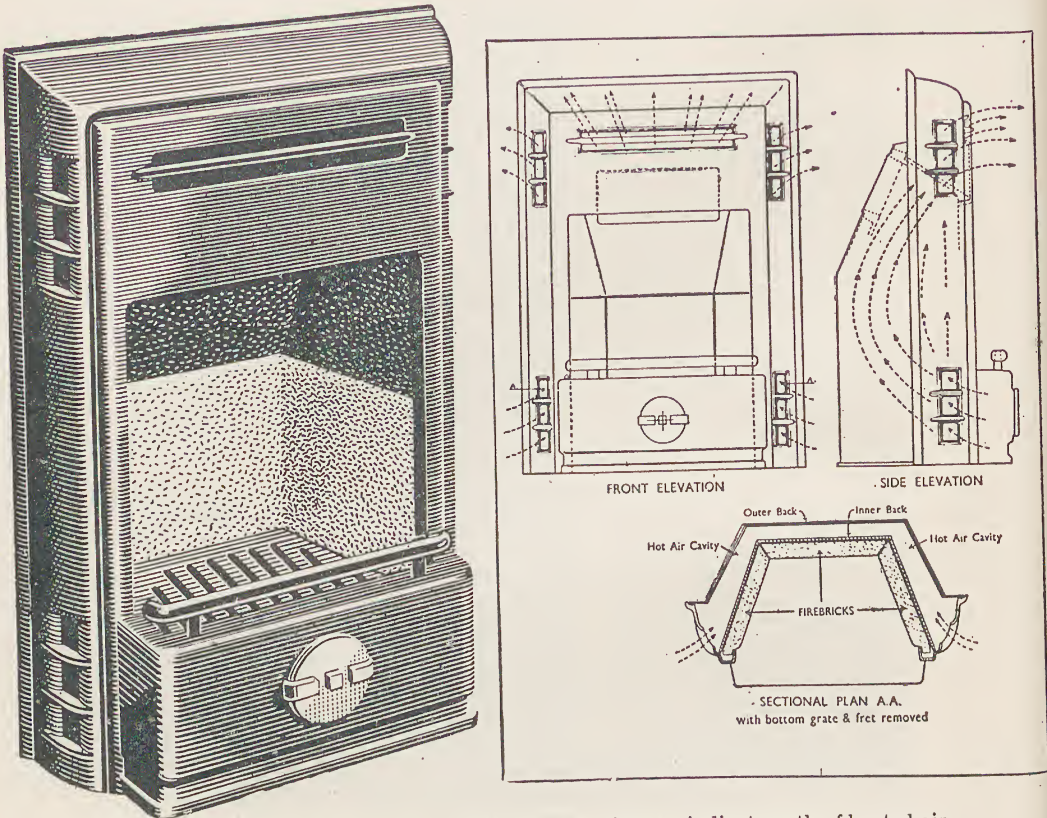


Fig. 80.—Projector heating unit. Dotted lines in diagram indicate path of heated air.
(*Courtesy Allied Ironfounders, Ltd.*)

ashes without scattering. These boilers are made in six sizes, suitable to accommodate from two to fifteen radiators.

The above boiler is suitable for the combined system of warming and hot-water supply ; and for this a cylinder of suitable capacity is placed above and near the boiler, having a flow led off it for the domestic supply.

The Radiator used in conjunction with this boiler may be taken as typical, and is made up of sections varying in number according to the amount of heating surface required. The sections are joined by threaded, tapered nipples, the water thereby flowing from one section to another. A valve is fitted to each radiator, which affords control of the flow of water and in consequence of the temperature also.

Wall Radiators are to be obtained, also in sections, but the sections are flat, and filled in with heating plates. These radiators are designed to be fixed to the wall, thus leaving the floor space free.

The Various Systems of Heating by Hot Water as given by Mr. Stanford in *Central Heating and Hot-Water Supply* are: (1) the two-pipe rising main system; (2) the two-pipe underfed system; (3) the one-pipe rising main system; (4) the one-pipe ring main system; (5) the overhead dropping main system; and (6) the two-pipe dropping main system.

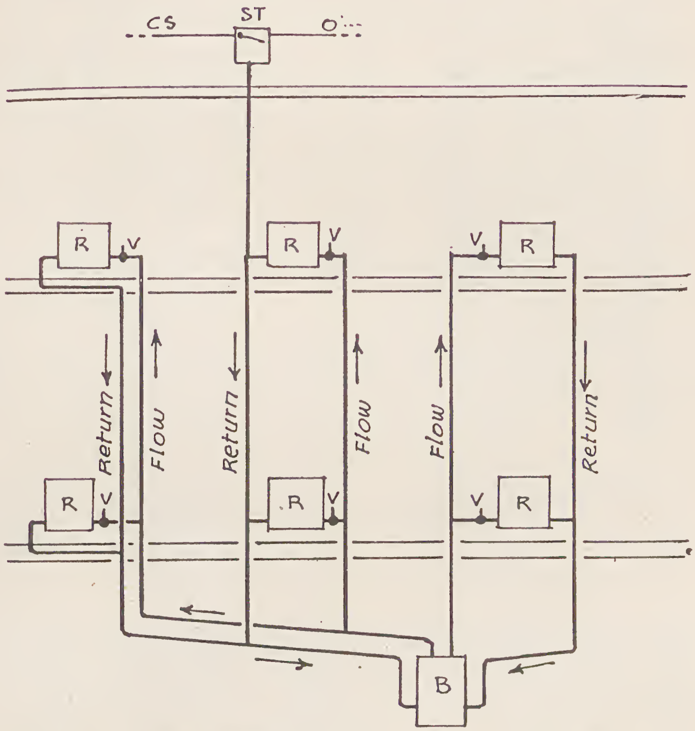


Fig. 81.—Diagram of the two-pipe system of heating.

In the two-pipe rising main system each radiator is connected at the top to a flow pipe and at the bottom to a return pipe. The two-pipe rising main system is suitable for low buildings with cellars for the boiler. Each radiator is connected direct to flow at the top, and to return at the bottom. The one-pipe rising main system is particularly suitable for low-built houses in which a heating system is required to be installed after erection. In this system each radiator is connected at the top on the flow side and at the bottom on the return side of the one-flow pipe, which is eventually returned to the bottom of the boiler.

The one-pipe ring main system is particularly suitable for a one-storey building with no cellar or basement, the boiler being on the floor and the radiators slightly raised. Wall radiators would be especially suited to this system. The return of the flow pipe is made above the ceilings.

In the overhead dropping main system all the hot water is first taken up to the top of the building and passed down by gravity to the radiators.

The two-pipe dropping system is an improved form of the last, the flow pipe being direct to each radiator and the returns also separate.

Open Fires are now to be obtained at the back of which there is situated

reason of the small volume of water in the boiler, due to the restricted area of the waterways. The fire being thus isolated, it is possible to set this boiler on a wooden floor.

There is a series of dampers, and by care in the use of these the draught may be controlled and the fire maintained for several hours without attention. A loose pan is fitted under the ash-pit for the removal of

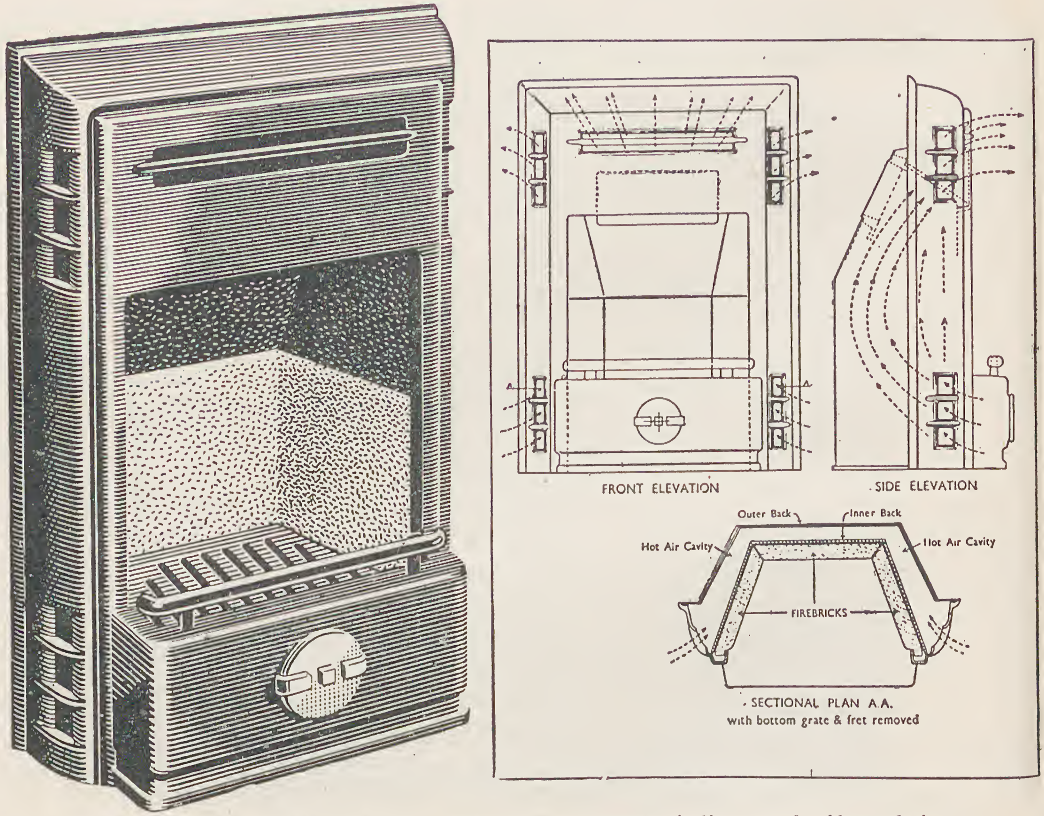


Fig. 80.—Projector heating unit. Dotted lines in diagram indicate path of heated air. (*Courtesy Allied Ironfounders, Ltd.*)

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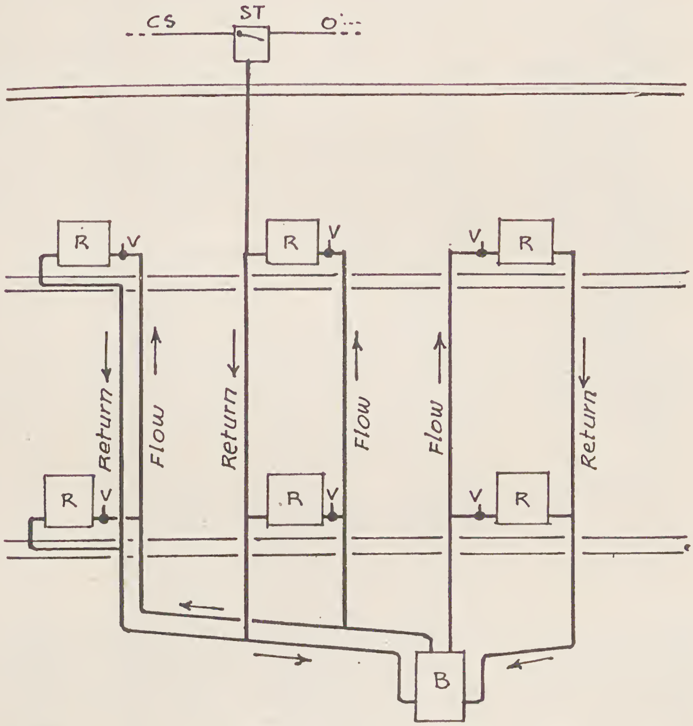

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The one-pipe ring main system is particularly suitable for a one-storey building with no cellar or basement, the boiler being on the floor and the radiators slightly raised. Wall radiators would be especially suited to this system. The return of the flow pipe is made above the ceilings.

In the overhead dropping main system all the hot water is first taken up to the top of the building and passed down by gravity to the radiators.

The two-pipe dropping system is an improved form of the last, the flow pipe being direct to each radiator and the returns also separate.

Open Fires are now to be obtained at the back of which there is situated

a small boiler capable of heating from one to four radiators or, alternatively, a 25/35-gallon hot-water cylinder for domestic use. The boiler is so situated that it is entirely surrounded by the heat from the open fire; and the flues, being vertical, are not liable to choke.

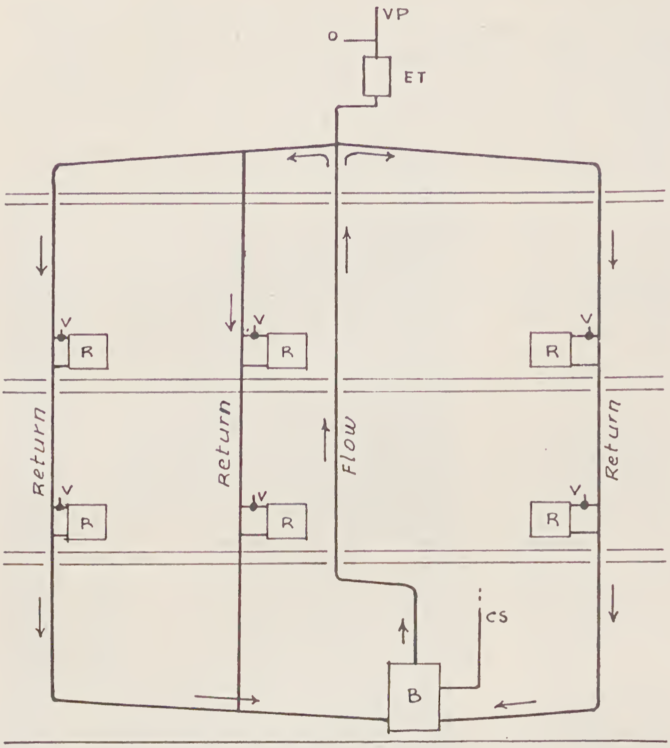


Fig. 82.—Diagram of the drop system of heating.

GAS HEATING

Gas is used for heating the hot water for central heating as well as for cooking. In the "Ideal" gas boiler (Fig. 83) a thermostatic control regulates the gas supply, the control being of the relay type. A graduated thermostat (A) is in circuit with the control valve (B), which must be fixed truly horizontal, through secondary tubes (C), a small quantity of gas flowing up from the control valve and passing down from the thermostat to the escape jet (D), where it is allowed to burn. As the desired temperature of water at the boiler is attained, the thermostat throttles the flow of gas through this secondary circuit, causing an increased pressure above the diaphragm in the control valve, which, working against the main gas supply pressure below the diaphragm, closes the valve, and so cuts down the main supply to the burners to the minimum required for the self-pilot flames. The "snap" effect of reducing to the self-pilot consumption takes only a few seconds. The boiler is therefore working at its maximum operating efficiency until the desired temperature is attained.

Self Pilot.—The bypass set-screw (E) under the control valve (B) permits regulation of the gas required to support the self-pilot flames. The burner jets used are of the luminous type, and are perfectly safe when burning with a very small flame at each jet; 5 per cent. of the rated consumption is ample for this purpose, giving a flame $\frac{1}{4}$ inch high.

Governor.—The governor is adjusted to give the gas pressure required for the rated consumption, and should be fixed perfectly horizontal. A

tapping is provided at the free end of the burner manifold (G), wherein the fitter may screw a $\frac{1}{8}$-inch cock in order to attach a gauge and determine the pressure. The rated consumption is obtained when the pressure is governed to give from 18 to 20 tenths water column with the burner taps (H) closed.

In cases where the return tapping on the thermostat side of the boiler is used, it will be necessary to fit the street elbow (J) provided to connect the governor to the control valve in order to clear the connection. The governor may be fitted in any position between the meter and the control valve, but where possible it should be connected immediately next to the control valve.

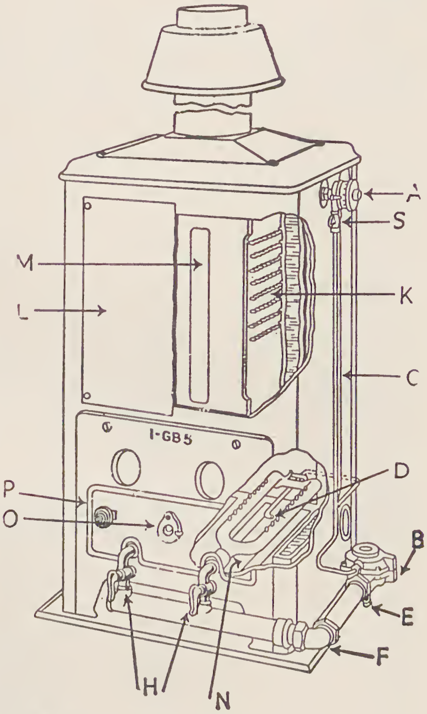


Fig. 83.—The "Ideal" gas boiler.

Cleaning of Flues.—The pin heating surface of the boiler (K) requires cleaning every few months, and a brush is provided for this purpose. Access to this pin surface is obtained by removing the detachable front panel of the jacket (L) and the cast-iron flue covers (M). To remove the latter, loosen the brass screws, raise upwards and then forwards. Before cleaning the flues, to avoid deposit entering the jets, either disconnect the burner at the union elbow (F) or cover the burner jets with paper or cloth to receive the deposit. The slotted tray (N) under the burners directs the air supply to the jets, and also shields the flames from possible floor draughts.

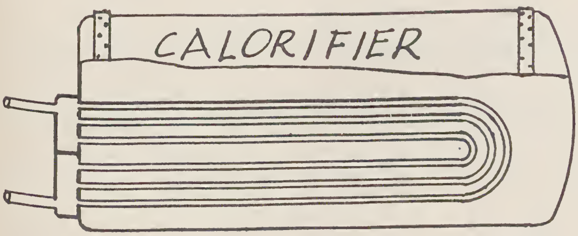


Fig. 84.—In a calorifier the hot water from the boiler passes through the pipe coil and the water in the body of the cylinder is indirectly heated.

Lighting.—When lighting, a lighted taper is applied through the lighting hole (O), after all the burner taps have been closed. Placing the flame of the taper over the nearest jets, the corresponding burner tap should then be turned on. The gas will ignite quietly. Where boilers have more than one burner, the taps of the other burners may then be turned on in their order from the operating burner, when they also will light quietly. The burner taps should never be turned on before applying the light, but always afterwards.

The small tap (S) provided near the thermostat must be open, *i.e.* in the vertical position, otherwise the control cannot operate. To shut off the gas supply entirely, this small tap must be closed, as well as the burner taps.

In mild weather, or for a night run, one or more of the burners in multi-burner boilers may be turned off and the thermostatic control allowed to function on the remaining burner or burners. This is

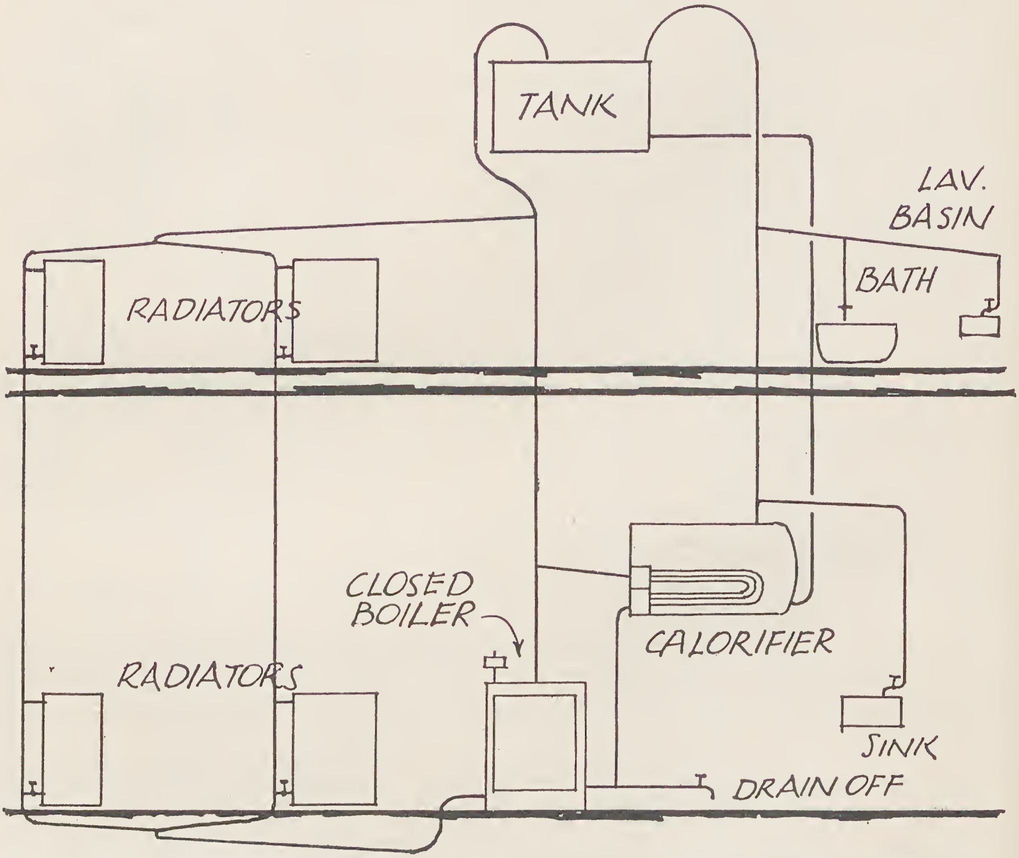


Fig. 85.—Calorifier used with closed boiler to supply hot water to radiators as well as to bath, lavatory basin, and kitchen sink.

sometimes preferable to allowing the thermostatic control to work on all the burners.

Should circumstances ever occur whereby the gas is accidentally extinguished, the burner and thermostat taps should be immediately turned off, and the boiler flues and chimney be given sufficient time to ventilate before relighting.

OIL HEATING

The burning of heavy crude oil under boilers in place of coal has been adopted in some cases in the past for large heating installations. The

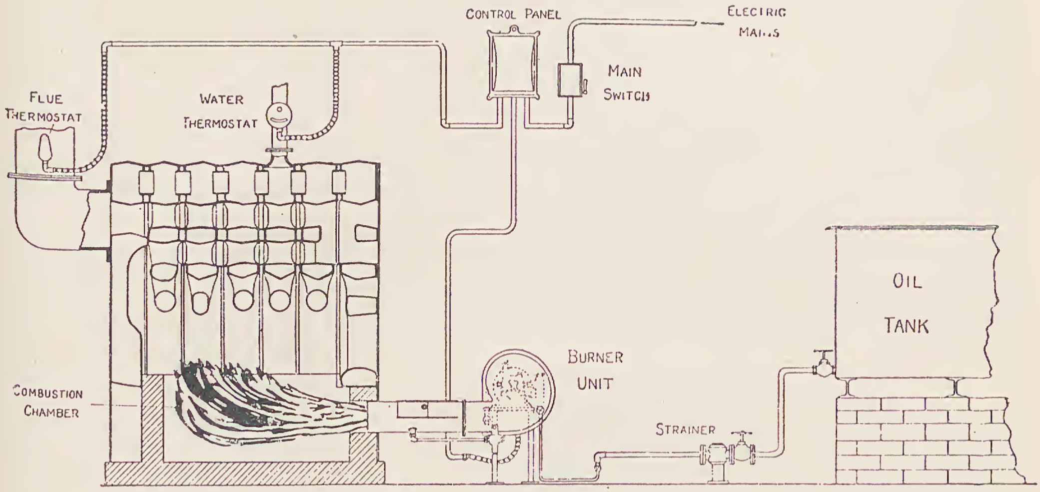


Fig. 86.—Diagrammatic layout of oil heating plant. (*Laidlaw, Drew & Co., Ltd.*)

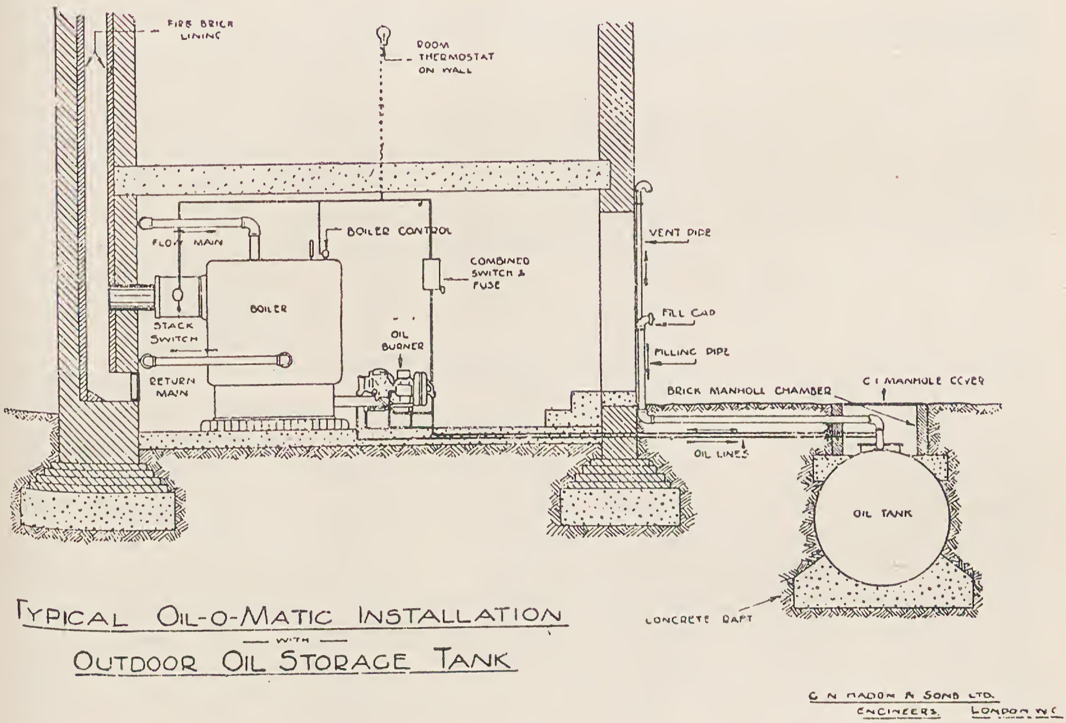


Fig. 87.

disadvantages attendant on the use of crude oil, due to the pressure required for the volatilising of the oil and the consequent noise issuing from the blast, have made it undesirable for domestic or public building use. However, a new invention has overcome these defects, as it burns light fuel oil and is noiseless.

In America this new type of oil burner has met with an enthusiastic reception from the general public, and it is rapidly displacing the use of coal for central heating throughout that country.

The advantages of the new system are that it confers a cleanliness and convenience hitherto unobtainable in central-heating installations. Moreover, it effects reductions in the cost of fuel consumption that are impossible with coal. This oil burner can be installed in any existing warm-air, hot-water, steam, vapour, or vacuum heating plant in a few hours. The oil fuel is stored in a tank, preferably underground, and is fed mechanically to the oil burner. Here it is atomised, ignited, and projected under the boiler as a fierce flame.

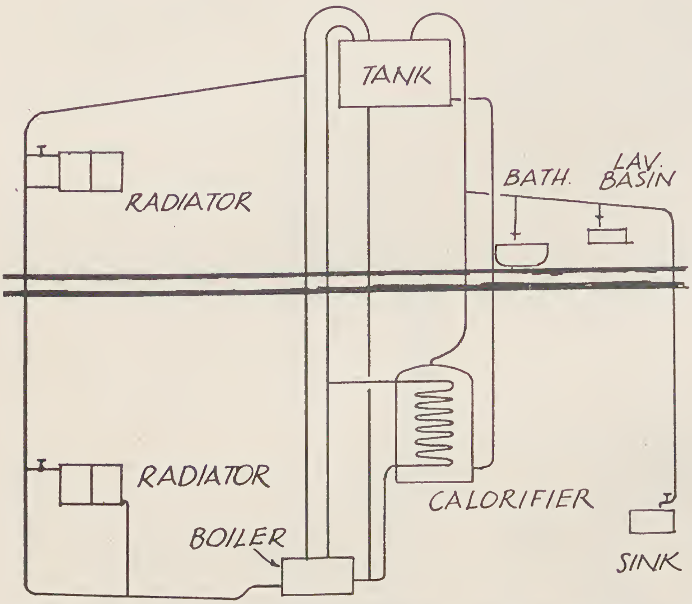


Fig. 88.—Calorifier used with kitchen-range boiler to supply hot water to a few radiators as well as bath, lavatory basin, and sink.

The whole process is controlled by a "thermostat." This may be fixed in any room in the building. It consists of a thermometer and a lever which is connected electrically with the oil burner. The lever moves along a plate showing degrees of temperature. It is set at the desired degree, and if the temperature shown on the thermometer is less than that desired, this action sets the mechanism of the burner working. As soon as the desired heat of the room (and of the whole house) has been achieved by the operation of the burner, the thermostat automatically closes down the burner, and the latter only functions again when the heat of the room has fallen below the desired level, when it runs again until the heat is normal. Consequently, by automatic intermittent burning a level of heat is maintained that is impossible when coal is used as fuel.

Other advantages of oil burning for central heating are that there is no noise and dirt attendant on the delivery of oil fuel. No ashes are left in

the fire box to burn to dust and permeate the whole house, as oil is entirely consumed. No ashbins are necessary, no soot is created, and the suspension of the whole system for periodical cleaning is never required.

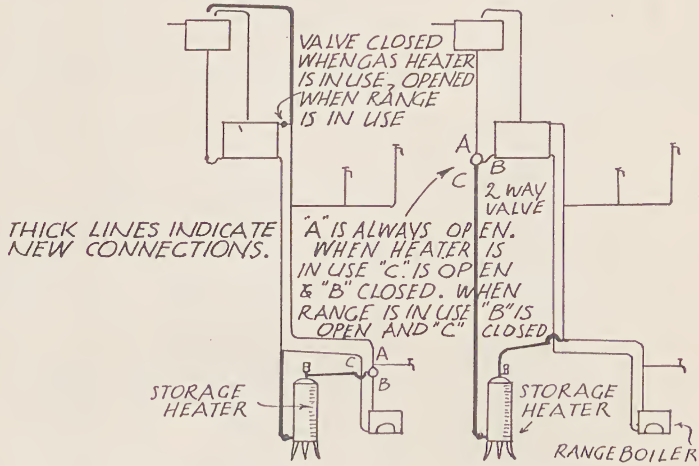


Fig. 89.—Two methods of connecting gas-storage heater as alternative to range.

The final attraction that must surely make central heating of this description an essential of the modern home is that it is more economical than heat derived from coal.

The cost of coal and oil fuel per unit of delivered heat is the same, but oil gives 10 per cent. more boiler efficiency than coal, and only 60 per cent. of the coal used under the boilers actually produces heat. The remainder is lost in starting fires, losses in transit, in ash, and in unconsumed fuel in the ash. Furthermore, oil fires can be closed down and started up immediately, so that no fuel is wasted in the necessities of banking and starting up that the use of coal involves.

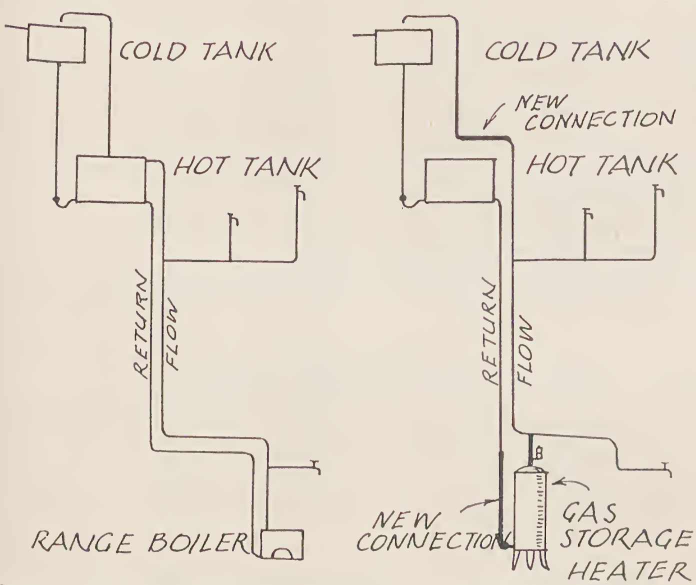


Fig. 90.—(*Left*) Existing tank system. (*Right*) Storage heater fixed in place of boiler.

It will be seen, even from this brief account, that an oil burner, such as the one described, renders heating as convenient as the turning on of electric light, and that any objection to central heating must fade before the ideal cleanliness and convenience that are assured by the installation of an oil burner.

ROOM TEMPERATURES

(Outside temperature being 32° F. = freezing.)

	°F
Churches	55–60
Conservatories and greenhouses	60–70
Factories:	
Light work	60
Heavy work	55
Garages [1]	45
Hospitals and Asylums:	
Wards	65
Sitting-rooms	65
Bedrooms	55
Operating theatres	80
Corridors	60
Hotels: *see* Residences.	
Ball-rooms	50–55
Museums	55
Offices	60–65
Residences:	
Sitting-rooms	60–65
Halls	55–60
Bedrooms	52–55
Staircases, corridors, bathrooms	55–60
Restaurants	60
Schools:	
Classrooms	62
Babies' rooms [2]	65
Central hall	60
Passages, corridors, staircases	55
Gymnasium	50
Shops and showrooms [3]	60
Stables and cow-houses [4]	50
Swimming baths:	
Dressing boxes	60
Temperature of water in plunge baths	70–75
Theatres, cinemas, etc.:	
Auditorium	55–60
Dressing-rooms	60
Stage [5]	55
Workshops, *see* Factories.	

[1] Just sufficient to prevent freezing of cylinders. (*Note.*—Heating of garages must always be accompanied by efficient ventilation—winter and summer.)

[2] Most school authorities demand a fire to be kept up in cold weather, which should bring the temperature up to 60–65°.

[3] Here the problem is to adjust needs of staff and comfort of customers.

[4] In small establishments, with a few beasts and good ventilation, artificial heating is rarely necessary.

[5] Heating must be so arranged as to avoid draughts from back of the stage to auditorium.

SIZE OF DIRECT RADIATORS (STEAM HEATED)

To obtain size of direct radiators, sufficient to raise room temperature to 60° F. when external temperature is 30° F.:

$$S = \frac{A}{4} \times \frac{B}{40} + \frac{C}{400},$$

where S = radiation in sq. feet; A = glass surface in sq. feet; B = exposed surface in sq. feet; C = cu. contents in cu. feet.

The above is useful for very large rooms or buildings; for greater accuracy use:

$$S = \frac{30A + 8B + C}{270}.$$

FORMULA FOR HOT-WATER HEATING

The radiating surface in hot-water heating is found as follows:

Ordinary two-pipe system: $R = (\cdot25w + g)c$.

Single-pipe overhead system: $R = (\cdot25w + g)c^1$,

where $R =$ direct radiation in sq. feet; $w =$ exposed surface of wall in

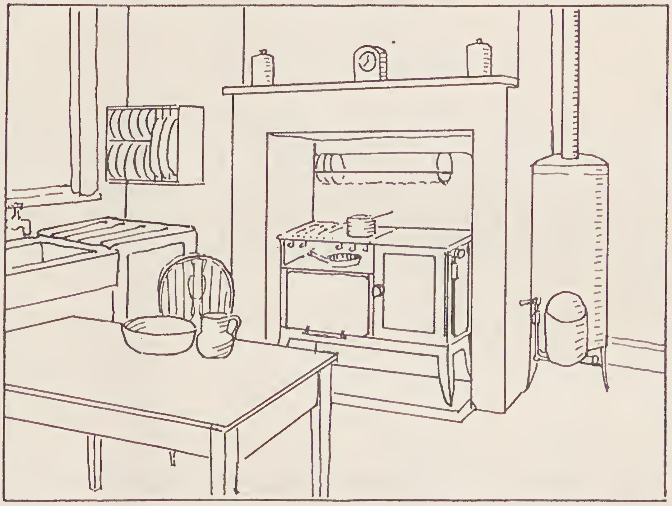


Fig. 91.—Showing gas-storage heater fixed in corner of kitchen with gas range in the fireplace.

sq. feet; $g =$ glass surface in sq. feet; $c =$ a factor—·35 for ground-floor, ·32 for first-floor, ·3 for second-floor. $c^1 =$ a factor—·4 for ground-floor; ·37 for first-floor; ·35 for second-floor.

RATIO OF HOT-WATER RADIATING SURFACES TO SPACE TO BE HEATED

Description of room or place.	Ratio of radiating surface to cu. space to be heated.
Living-room, one side exposed	1–80
Living-room, two sides exposed	1–70
Living-room, three sides exposed	1–60
Bedrooms	1–100
Hall and bathroom	1–50
Schoolrooms and offices	1–80
Factories and shops	1–110
Theatres and churches	1–100

CHAPTER 4

VENTILATION

VENTILATION is the maintenance of a supply of fresh air within and the removal of vitiated air from a building; and though this has, in the past, generally been considered only so far as the air to be breathed in the rooms of a building is concerned, in more recent times attention has been directed to the necessity for ventilating the interior of the structure of a building.

This is, in part, due to the fact that with an increased appreciation of the value of and pleasure to be obtained from fresh air, it has become much more general to live with open windows, and in consequence there is not the same need for more or less intricate ventilating systems, so far, at least, as the ordinary dwelling house is concerned. In public buildings, schools, hospitals, theatres, and churches, where large numbers of people are congregated within comparatively small areas, the subject is of growing importance.

Need for Ventilation.—Shortly put, the scientific reasons underlying the need for fresh air, of which fact there are still found a surprisingly large number of persons remaining to be convinced, are firstly, that oxygen is essential to human life, and secondly, that the human body gives off in exhalations, or breathing out from the lungs and from the pores of the skin, certain gases that are poisonous.

The standard of air purity is reckoned by the proportion of carbon dioxide gas which the air contains, because this gas is breathed out, and with it are even more dangerous gases which are more difficult to detect. It is accepted that air in habitable rooms should never contain more than ·06 per cent. of carbon dioxide (CO_2).

Air within a building may also be vitiated by other causes than the exhalations of human bodies. Chief amongst these are defective drains, decomposition of animal and vegetable matter, too close proximity of insanitary stables, cow-byres and piggeries, and the decay of the materials of which the building is composed. Too great a percentage of moisture vapour in the air arising from damp soils, marshy lands, lakes, ponds, and streams is also a cause of conditions which are bad for the health, and which require increased ventilation as a remedy. Water vapour is also contained in the breath of human beings and in an even greater degree in that of animals, and may also arise from cooking and certain industrial operations.

The other gases detrimental to health contained in vitiated air are ammonia, nitrous acid, sulphuretted hydrogen, and sulphur dioxide: and of these, decaying animal matter is the main source of ammonia, which also arises from insanitary stables, etc., and urinals. Coke and coal burning in unventilated rooms where there is a downdraught in the flue is a frequent cause of sulphur dioxide, and badly ventilated or stopped drains are the most usual causes of sulphuretted hydrogen.

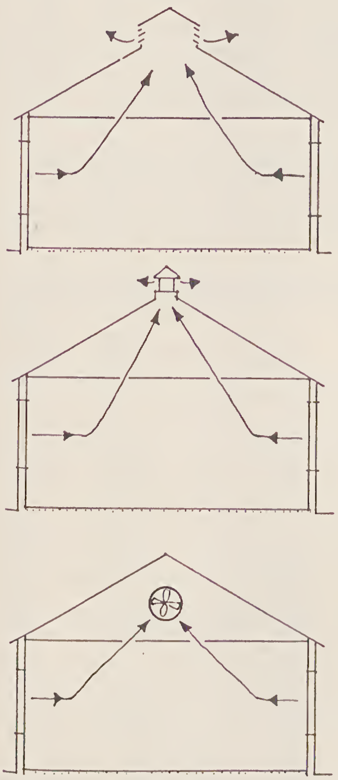


Fig. 92.—Inlets through windows or vent openings. (*Top*) Outlet through lantern louvres on roof. (*Middle*) Outlet through extractor ventilator. (*Bottom*) Outlet through mechanical extract.

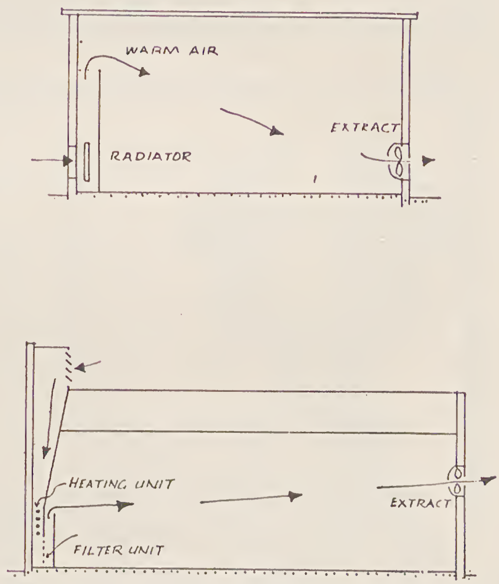


Fig. 93.—(*Top*) Air heated at inlet and passed into room at level above working plane with extract-fan outlet at low level. (*Bottom*) Air taken from high level, heated and filtered and drawn out by extract fan. This system prevents dust entering the room.

As was explained in the chapter on Timber, CO_2 is taken from the air into the leaves of trees and flowers to form chlorophyll, and oxygen is set free and given out into the air.

Principles Underlying Ventilation.—As with the hot-water system, the main principle which is made use of in natural ventilation systems is that air when heated becomes lighter, bulk for bulk, than when cold, and consequently the warmed air rises above the cooler. And as in an enclosed space, such as an inhabited room, the source of heat is usually near the floor, the result is that circulation is set up in the air within the

room, the stages of this being, first, the warmed air rises towards the ceiling and the cool air sinks ; then, as the cooler parts of the room, *i.e.* the upper parts, cool the warmed air, and the warmer parts, *i.e.* the fire and neighbourhood of any person within the room, warm the cooled air, there is again a change of position, which, being repeated, becomes a continuous circulation.

Such a continuous rising of warmed vitiated air and its replacement by fresh air is the purpose of any natural system to make use of. Systems there are in which fans extract vitiated air, and to that extent they may be looked upon as mechanical ; but the natural tendency of warmed air to rise is made use of even here to the extent that such fans or exhausts

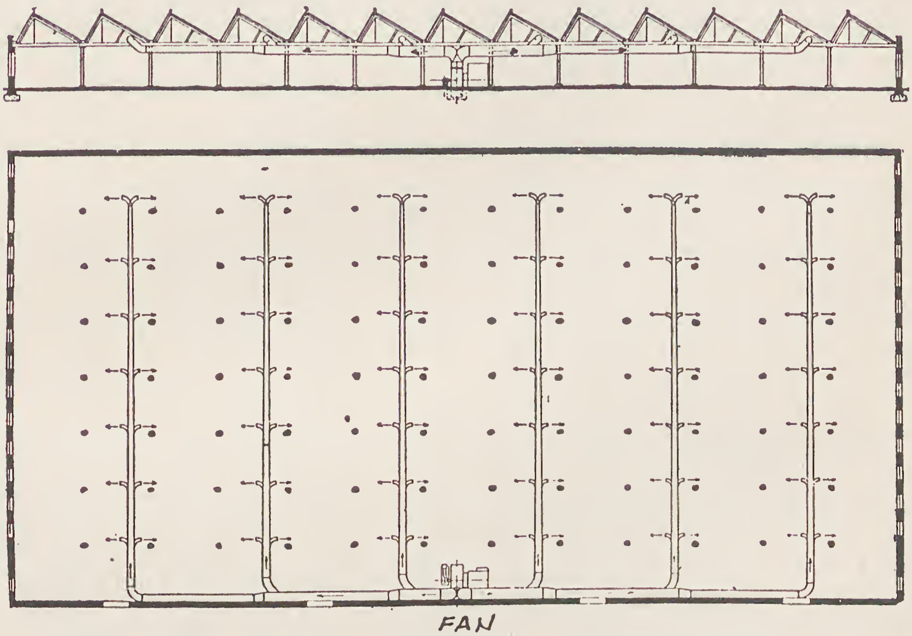


Fig 94.—Plenum ventilation system with overhead ducts and outlets. Fresh air is forced into the building through the duct outlets and vitiated air forced out through windows and doors.

are situated at points to which the vitiated air naturally rises. In systems in which the fan or exhaust is situated below the building, it might seem that this principle was superseded ; however, though the current is turned towards an outlet at a low level, the circulatory principle of heated air is made use of even in these.

NATURAL VENTILATION

The systems employed in ventilation, therefore, are divisible into : (1) natural, and (2) mechanical, and as has been explained, both types make use of the natural law in relation to warm air.

Consequently, the simplest way to employ the natural law in ventilating a room is to provide an inlet at a low and an outlet at a high level ;

and systems there are, as is explained later, involving such inlets and outlets and in some vent ducts or shafts to a cowl or suction turret, in which this elementary scientific principle is made use of.

In spite of this natural tendency for heated air to rise, it is generally found sufficient for ventilating the ordinary room if the door, windows, and fireplace be relied upon—the inlets being the door and windows, and the outlet—though not high in the room—being the fireplace. This draught up the chimney can be regulated by means of vent ducts let into the edge of the hearth and conducted to the underside of the fire as described in the chapter on Brick Fireplaces, Chapter 3, Vol. II.

Though it is correct to say that the fireplace opening is at a low level in the room, it communicates by the flue to an opening high up above the room, and the tendency of the air is to rise by whatever channel or opening is presented. Of course, when a fire is burning the principle is easily seen, as the heat from the fire causes the air to rise up the chimney flue, setting up a suction at the windows and door. But even when there is no fire burning there is, in ordinary conditions, a current of air passing in at these openings and out up the flue.

This last is occasioned by conditions outside the building, where the air, warmed by the heat of the sun radiated from the walls and roof, is caused to rise in the immediate neighbourhood of the building, with the natural result that a suction is experienced at the top of the chimney, resulting in drawing the air from the room up the flue. The methods by which windows may be made to assist in this supply of fresh air has been discussed in the chapter on Joinery, Chapter 9, Vol. III.

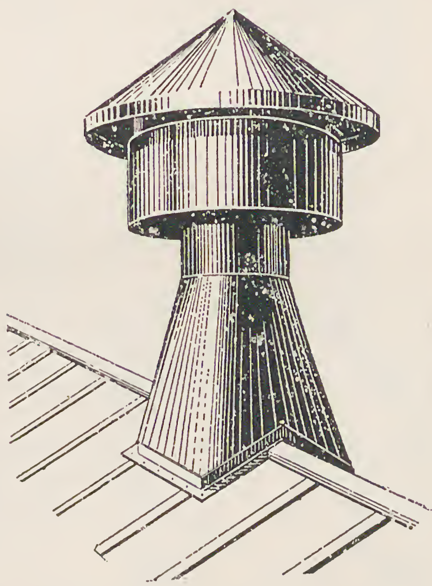


Fig. 95.—The "Coupard" cowel.

It may be thought that as the sun, even in summer, does not always shine, this natural system would be intermittent, but observations prove that one side of a building, and also, to an extent, the roof, is always warmer than the other side. This warm side is not always the same one, but may alter with outside conditions; the fact remains that there is always a difference of temperature to be felt on different sides of a building.

This discovery has been put to practical use in a natural system of ventilation known as the "Knapen" system of horizontal differential aeration, which high-sounding title means little more than that passage for the air through vents across the interior of a building from the cold side to the warm side is afforded to enable the natural law that heated air

rises to work, with the result that the interior of the building is thereby ventilated.

The "Knapen" System.—This system of aeration operates on very different lines from any other method. Instead of employing force to circulate the air, this system utilises the services of nature, and operates by persuasion alone, so that its object is attained without bother and at little expense. M. Knapen theorised on a totally different hypothesis from that upon which most systems are based, and, recognising that air can be displaced laterally with a difference of only 0·5° C. in the temperature, a perfectly effective method of aeration was devised, which is not subject to the disabilities of the other methods. The advantage lies in the fact that the temperature on two opposite sides of a building always differs (due to different orientation), and as the colder side is naturally heavier, a steady pressure is exerted, which creates a movement of the air within the building. As one side is always colder than the other, the movement is automatic and persists indefinitely, any variation in the temperature as the sun moves round merely altering the direction in which the air moves. Thus the most perfect continuous and natural aeration of the premises is assured.

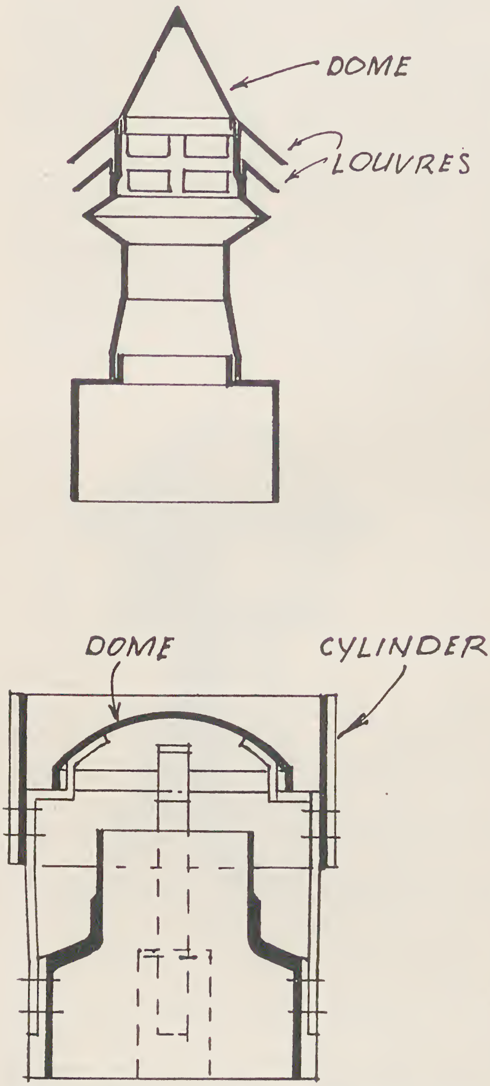


Fig. 96.—(*Top*) "Everite" asbestos-cement ventilator. Two-louvre type. (*Bottom*) "Everite" asbestos-cement extractor.

Additional Vents to the windows and fireplaces were at one time customary to be fixed in the ordinary-sized house, but as none of the methods employed ever worked quite satisfactorily, they have for the most part been discontinued. They are, in fact, unnecessary if proper use is made of the door, windows, and fireplace. But as it is likely that, with the growing use of electricity for heating and a consequent disappearance of the flue, we may expect to see a return to additional aids, it may be helpful if the salient features of some of these be recorded here

The simplest way of adding to the inlet and outlet of air to any room is to fix ventilating gratings in the outside walls, the proper position for the inlet being near the floor and for the outlet near the ceiling. But, as has been explained, owing to the varying conditions of temperature in the neighbourhood of different walls at different times, it is generally found that such vents do not function as intended, being inlet and outlet alternatively in accordance with the atmospheric changes. Consequently, the best position to fit the vents is at an equal height above head level, say, 6 feet to 7 feet above the floor.

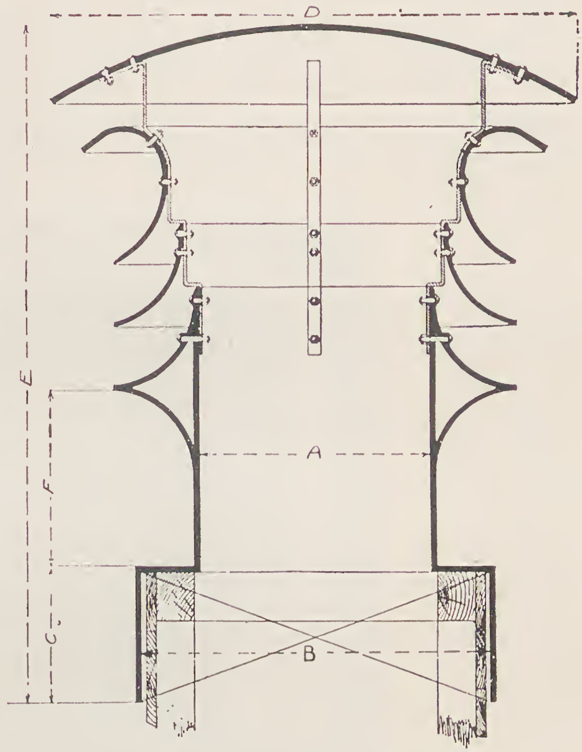


Fig. 97.—" Aerolete " asbestos-cement ventilator. Section showing fixing to wood.

To work in conjunction with the foregoing outlet vents are required; and as the success of these and any other method of ventilation depends to a great extent on the proper dimensions in relation to the cubic contents of the room and the proper proportioning of one to the other, it is advisable that a specialist should be consulted in this matter where it is required to fix vents, and still more so a ventilating system to buildings of any size larger than the small house or cottage.

Data.—The following approximate data will be found helpful in proportioning these areas for the small house.

AMOUNT OF AIR REQUIRED FOR VENTILATION

Rooms.—*Living-room* per head. 750 cu. feet.
Bedrooms per head. 1,000 cu. feet.

Buildings.—*Schoolrooms* per head per hour. 1,800 cu. feet.
Churches per head per hour. 1,800 cu. feet.
Theatres and Auditoria per head per hour. 2,000–2,500 cu. feet.
Hospitals per bed per hour. 4,000–6,000 cu. feet.
Stables per horse per hour. 1,200–1,600 cu. feet.
Cow Byres per cow per hour. 1,000 cu. feet.

One Person requires from 3 to 4 cu. feet of air per minute.

A Man at Work requires 6,000 cu. feet per hour.

Gas.—One foot of gas burnt per hour exhausts 1,800 cu. feet of air per hour.

The Size of Ducts may be estimated from the following formula :

$$\left.\begin{array}{c}\text{Sectional area of}\\ \text{duct in feet}\end{array}\right\} = \frac{\text{Quantity of air in cu. feet per minute.}}{\text{Velocity in feet per minute.}}$$

Shape and Size of Ducts.—The insides of air ducts should be sheeted with metal to reduce the friction. Brick flues should be lined with tin or

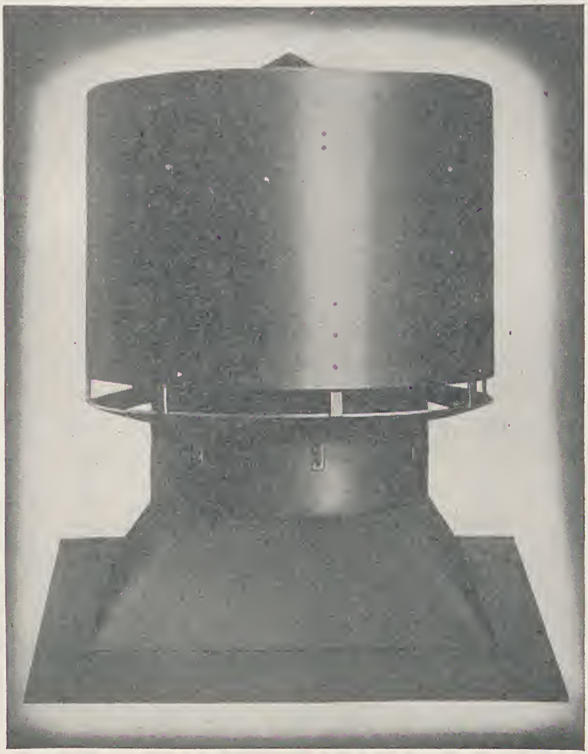


Fig. 98.—Roof ventilator, designed to extract air by natural means. (*Courtesy of Cellactite & British Uralite Co., Ltd.*)

zinc. Circular ducts are best, and rectangular ducts should be made as nearly square as possible.

Exhaust Vents are satisfactory only when formed with separate flues or ducts. To save expense a combined shaft may be used ; but the old-fashioned practice of fitting a vent with a mica flap into a smoke flue should never be allowed. The mica flap never forms a satisfactory seal against downdraught, and the inlet of additional air to that for which the flue was designed cannot fail to upset the updraught of the fireplace flue.

TABLE SHOWING QUANTITY OF AIR IN CU. FEET PASSING PER MINUTE THROUGH A VENT 12 × 12 INCHES OR EQUIVALENT

Height of venti-lation in Feet.	Difference between temperature in room and external air.					
	5°	10°	15°	20°	25°	30°
10	116	164	200	235	260	284
15	142	202	245	284	318	324
20	164	232	285	330	368	404
25	184	260	318	368	410	450
30	201	284	347	403	450	493
35	218	306	376	436	486	531
40	235	329	403	465	518	570
45	248	348	427	493	551	605
50	260	367	450	518	579	635

New Standards for House Ventilation.—Important standards for the ventilation of dwellings are defined in British Standard Code of Practice CP 6 : 1945. The Code recommends that for every room throughout a house a system of ventilation be provided comprising outlets through which air can be withdrawn, and inlets through which fresh air can enter. It gives data as to the number of square inches of ventilation area required for each type of room, pointing out that where there is a chimney flue this may provide the extract, but that intake is essential, the latter being provided by air bricks which must be controllable. Where there is no chimney flue, both intake and extract must be provided by controllable air bricks.

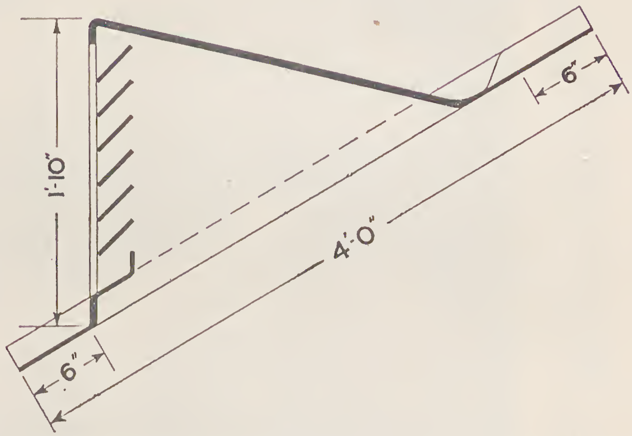


Fig. 99.—Section through standard " Turnall " Trafford tile ventilator.

The Code points out that it is undesirable to have too rapid an air change, as this would impose an excessive demand on heating for a comfortable degree of warmth to be maintained.

Recommended rates of air change in cold weather :

The Code recommends the following :

Living-room	600 cu. feet of air per hour per person.
Bedroom	600 ,, ,, ,, ,, ,,
Kitchen (cooking for not more than six persons) . . .	1,000 ,, ,, ,, ,, ,,
Halls and Passages . . .	1 air change per hour.
Bathroom and W.C. . .	2 air changes per hour.

Constant-flow Ventilators.—Air bricks with or without adjustable shutters are liable to cause discomfort due to an excessive intake at higher wind speeds. The occupants of the room suffer draught, and frequently block up the air brick. If it is of the adjustable type, there is a tendency to leave it closed.

The Colt constant-flow ventilator solves the problem of controlling air change without draught, by the following means. The ventilator comprises a metal casing, housing self-adjusting vanes carried in silent plastic sleeves. These vanes permit the uninterrupted flow of air until, when windy conditions exist outside of the building, the rate of the incoming air approaches a speed which would be perceptible and cause a draught,

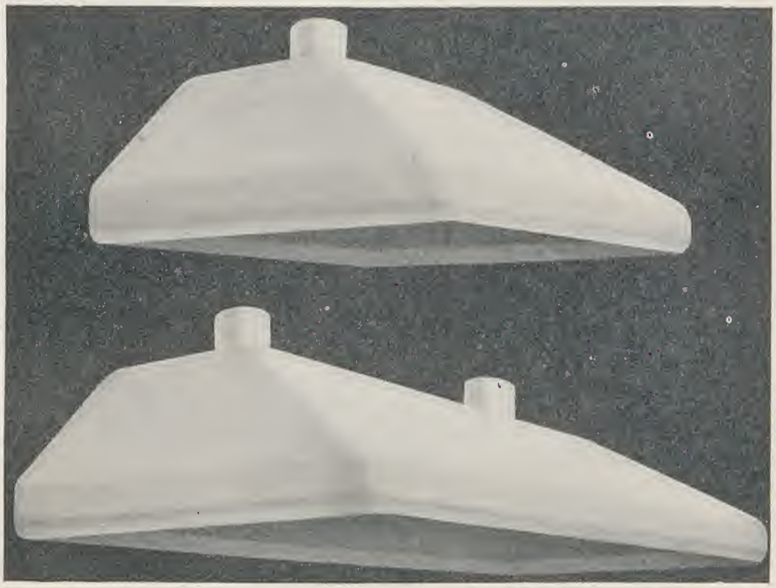


Fig 100.—Hoods with rounded angles and condensation channels, for collecting steam (*Courtesy of Universal Asbestos Manufacturing Co., Ltd.*)

the vanes gradually close, restricting the aperture, while automatically controlling the rate of delivery. Three sizes are made to conform to the Code of Practice requirements.

In fixing, the body of the ventilator is inserted into the wall opening and secured by four screws. On the outside face of the wall an ordinary air brick is fixed, though it is important that the air brick should have adequate free area. The ventilator can also be fitted to doors, windows, sheeting, and any prefabricated type of construction.

Combined System.—This consists of mechanically controlled ventilation for both inlets and outlets. While the plenum system is largely used for factories, the combined system is preferable for cinemas, offices, and other buildings where a high degree of ventilation control is demanded.

The combined system does not require opening windows and doors or any open apertures other than those serving the fans. Measures can be taken to exclude both external noises and mechanical noise from the fan equipment.

In places of entertainment the minimum volume of air per occupant is fixed by most local authorities at 1,000 cu. feet per hour per person, though in some cases it may be desirable to double this allowance. The combined system enables the allowance to be controlled.

A washer is usually provided to clean the air before it passes through the centrifugal fan. The air is then forced along a duct system through grilles. The fan is mounted on anti-vibration bearings, and there are flexible connections from fan to ducts so that vibration and noise cannot spread from the fan chamber.

The vitiated air is withdrawn by an extract fan through grilles and ducts. About 75 per cent. is mechanically withdrawn, the remainder passing out through exit doorways. The system has the same advantage as the plenum system in maintaining the atmosphere at a slightly higher pressure than the external atmosphere, and so preventing draughts.

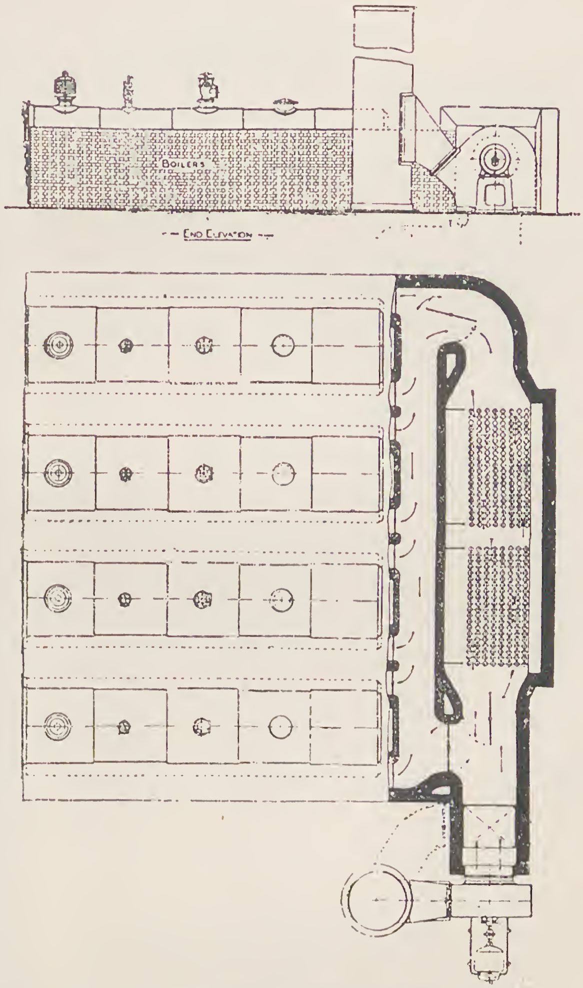


Fig. 101.—" Keith " induced-draught plant.

The ventilation will work upwards or downwards according to the relative placing of the inlet and outlet grilles.

The Upward System has inlet grilles about 8 feet above the floor, and the outlet grilles are usually placed in the ceiling. There is thus no draught from the inlets and the vitiated air and smoke are carried upwards.

The Downward System has fresh-air grilles in the ceiling, and the vitiated air is drawn out at or close to floor level, through grilles in the walls or under seats. In a cinema this method has the advantage of

drawing smoke downwards so that it does not drift into the projection beam.

Air Conditioning.—This differs from ordinary ventilation, as it cleans, humidifies, or de-humidifies, and heats or cools the air, as required. The system is now used in most large cinemas and theatres, and also in many factories where the processes used call for good and constant atmospheric conditions.

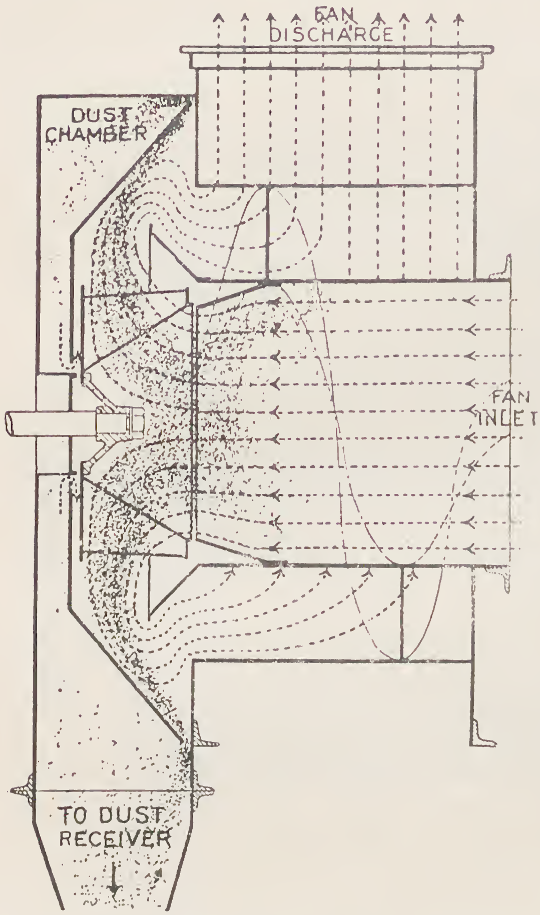


Fig. 102.—"Keith-Blackman" dust-separator fan.

Heating and refrigerating plant is incorporated in the air conditioner, and the whole system is regulated by sensitive automatic controls which take account of humidity as well as temperature.

MECHANICAL VENTILATION

Ventilation by fan is effected by the following systems:

(1) ***The Exhaust System,*** in which an exhaust fan is used to withdraw vitiated air from the room, fresh air being drawn in through windows, doorways, or vent apertures. This system is chiefly useful for drawing off disagreeable odours or deleterious fumes in factories and workshops.

The fan is usually fixed in a ventilating turret with exhaust outlet ducts connecting thereto, and is operated by an electric motor. The inlets used are of the type known as Tobin's tubes, which are wood metal-lined casings of the required sectional area, often heated internally with steam coils.

(2) ***In the Plenum System,*** also known as the hot-blast system, the air is forced into the building, causing the used air to be forced out and replaced by fresh and, if desired, warmed air.

The air is drawn into a chamber fitted with a fan and a heater, with flues or ducts conveying the air to the various rooms. As the air is drawn in under the pressure the inlet must be fitted with some form of air filter, such as a gauze screen, down which water trickles. Under the heated chamber next to the fan is a cool-air chamber or passage, by

which means the temperature of the air admitted to the ducts can be regulated. The inlets into the rooms are usually fixed at a height of 1 foot down from the ceiling, and the outlets are fixed near the floor level and directly beneath the inlets.

The types of fans used are the disc fan, the paddle-wheel fan, or the cone fan. The disc fan receives the air at one side and delivers it at the other. The paddle-wheel fan is formed of steel-plate blowers ; and the cone fan

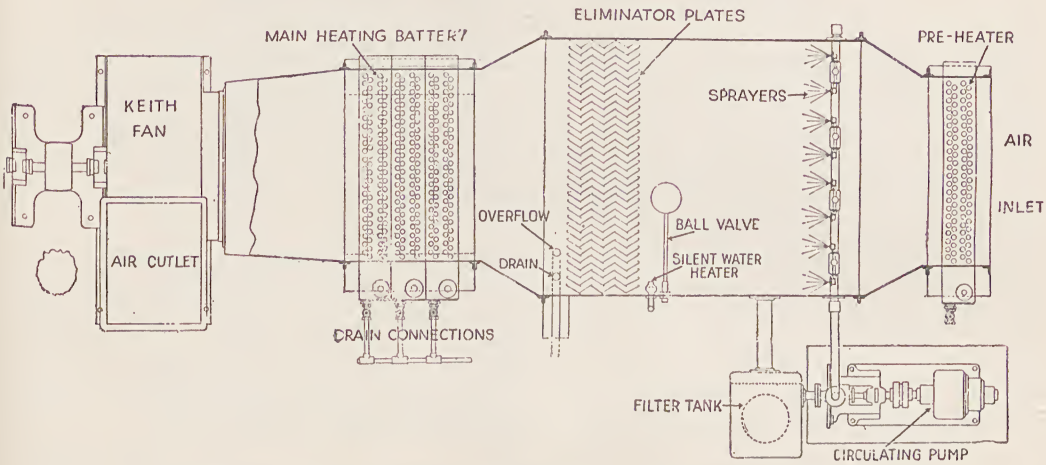


Fig. 103.—"Keith" fan. Heating battery, washer, and humidifier.

is a special type of paddle-wheel fan used chiefly in large plenum chambers under audience rooms. Fans are driven by means of water wheels or electric motors, and as they cause noise, the chamber must be insulated and in as distant a part of the building as possible.

Heated-air Inlet.—Ventilation systems of the ordinary natural kind work best when combined with a heating system, such as has already been described, and in this the hot-air heating system as used in America is helpful if the air is properly filtered.

CHAPTER 5

THERMAL AND SOUND INSULATION

THERMAL insulation in a building is the reduction of heat loss to a reasonable minimum by constructing walls, partitions, floors, and ceilings with materials which do not readily allow heat to pass through them.

Sound insulation is the reduction of sound transmission through walls, partitions, floors, and ceilings by constructing or lining them with materials which do not readily transmit sound.

It should be noted that the strength of a building has nothing to do with its insulating properties. Steel, which is one of the strongest structural materials, is a poor insulator both of heat and sound. Felt, which is structurally weak, is a good insulator. But it is desirable to select insulating materials which also are of structural use. Thick fibre-board, for example, may be used as an insulating lining.

THERMAL DEFINITIONS

Heat.—Heat is a form of energy. It varies in intensity, and from a scientific point of view it is better to think of relative intensities of heat rather than heat and cold.

The intensity of heat is measured in English-speaking countries by the Fahrenheit system, in which 32° F. is the freezing- and 212° F. the boiling-point of water.

Quantity of heat is measured in English-speaking countries in British Thermal Units (abbreviated as B.T.U. or B.Th.U.), this being the amount of heat which must be added to or subtracted from 1 pound of water to raise or lower its temperature 1° Fahrenheit.

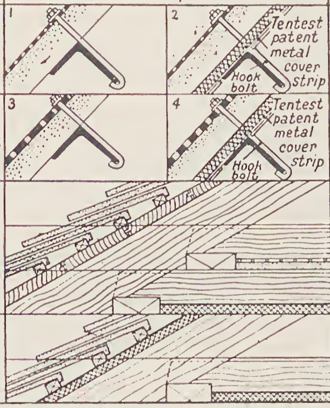
The transmission of heat occurs in three ways: by radiation, conduction, and convection, as already explained in Chapter 3.

Thermal Conductivity of a material is the amount of heat, expressed in B.T.U., which passes through 1 square foot of homogeneous material, 1 inch thick, in 1 hour for a temperature difference of 1° F. from face to face. The conductivity of a material is denoted by the symbol (k).

Thermal Conductance is the amount of heat expressed in B.T.U. transmitted in 1 hour through 1 square foot of non-homogeneous material, of the thickness actually manufactured or used, for a temperature difference of 1° F. face to face. It is denoted by the symbol (C), and applies to materials such as plaster-board or hollow-clay tiles to which the coefficient k would not apply.

PITCHED ROOFS

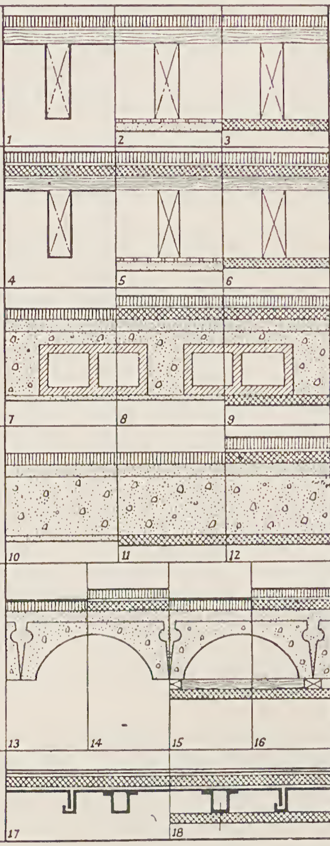
DETAIL OF CONSTRUCTION — *Scale: 1 inch equals 1 ft.*



BASIC CONSTRUCTION	FINISH	A Thermal transmittance in B.T.Us.	B Cost of heating plant at 5s. per sq. ft. radiation surface	C Fuel per annum in tons	D Cost of fuel per annum at 25s. per ton	E Total cost of heating plant and fuel over 20 years
Robertson's protected metal sheeting	1 *No lining*	0·9	£42: 5	5·58	£7: 0	£182: 5
	2 *5/8" Tentest lining*	0·28	13: 5	1·74	2: 4	57: 5
Corrugated asbestos-cement sheets	3 *No lining*	1·40	65:15	8·68	10:17	282:15
	4 *5/8" Tentest lining*	0·33	15:10	2·05	2:11	66:10
Tiles, T and G. boarding, wood rafters	*No ceiling*	0·56	26: 5	3·47	4: 7	113: 5
	Lath & plaster flat ceiling	0·32	15: 0	1·98	2:10	65: 0
	5/8" Tentest flat ceiling	0·23	10:15	1·43	1:16	46:15
Tiles 5/8" Tentest, wood rafters	*No ceiling*	0·41	19: 5	2·54	3: 4	83: 5
	5/8 Tentest ceiling (flat)	0·20	9:10	1·24	1:11	40:10

Fig. 104.

FLAT ROOFS



BASIC CONSTRUCTION	FINISH	A	B	C	D	E
Asphalte on 1 in boarding wood joists	1 *No ceiling*	0·53	£25: 0	3·29	£4: 2	£107. 0
	2 *Lath & plaster ceiling*	0·31	14:10	1·92	2: 8	62.10
	3 *5/8" Tentest ceiling*	0·23	10:15	1·43	1:16	46:15
Asphalte on 5/8" Tentest on 1 inch boarding, wood joists	4 *No ceiling*	0·28	13: 5	1·74	2: 4	57: 5
	5 *Lath and plaster ceiling*	0·21	10: 0	1·30	1:13	43: 0
	6 *5/8" Tentest ceiling*	0·16	7:10	0·99	1: 5	32:10
Asphalte on concrete and 4" hollow tile roof	7 *Plaster ceiling*	0·47	22: 0	2·91	3:13	95: 0
	8 *5/8" Tentest insulation plaster ceiling*	0·26	12: 5	1·61	2: 0	52: 5
	9 *5/8" Tentest insulation & ceiling*	0·19	9: 0	1·18	1:10	39: 0
Asphalte on 6" total concrete roof	10 *Plaster ceiling*	0·62	29: 5	3·84	4:16	125: 5
	11 *5/8" Tentest ceiling*	0·33	15:10	2·05	2:11	66:10
	12 *5/8" Tentest insulation, & ceiling*	0·21	10: 0	1·30	1:13	43: 0
Asphalte on Truscon-type roof	13 *No ceiling*	0·80	37:10	4·96	6: 4	161:10
	14 *5/8" Tentest insulation, no ceiling*	0·35	16:10	2·17	2:14	70:10
	15 *5/8" Tentest ceiling*	0·26	12: 5	1·61	2: 0	52: 5
	16 *5/8" Tentest insulation & ceiling*	0·19	9: 0	1·18	1:10	39: 0
Steel roof deck with 1/2" Tentest insulation	17 *No ceiling*	0·40	18:15	2·48	3: 2	80: 15
	18 *5/8" Tentest ceiling*	0·20	9:10	1·24	1:11	40:10

Fig. 105.

The above tables afford a ready means of comparing the effect of various types of construction on heating plant and fuel costs. A study of these will show that the additional expenditure on the structure of a building is frequently justified by consequent heating plant and fuel economies, and also that a light, cheap form of construction, suitably insulated, has a greater thermal efficiency than others more solid and costly. (*Courtesy of the Ten-Test Fibre Board Co., Ltd.*)

Thermal Transmittance is the overall air to air coefficient of heat transmitted from inside air to outside air through structure and surface films, expressed in B.T.U. per hour, per square foot, per degree Fahrenheit difference in air temperatures. It is denoted by the symbol (U).

Thermal Resistance of a combination of materials, or the resistivity of a single material, is the reciprocal of the conductance or conductivity, *i.e.* $\frac{1}{C}$, $\frac{1}{k}$, or $\frac{1}{U}$. It may also be defined as the number of hours it takes for 1 B.T.U. to pass through 1 square foot of a material, or combination of materials, for 1° F. temperature difference. Thus if the thermal transmittance of a wall is 0·5 it will take $\frac{1}{0{\cdot}5} = 2$ hours, for 1 B.T.U. to pass through, and the resistance is quoted as 2.

Surface Film.—Every solid body in contact with gas or liquid will have adjacent to it a thin film of stationary air or liquid which offers resistance to the passage of heat into or from the body, even though the main part of the air or liquid be in motion. The more rapid the motion, however, the thinner the film, and the less the resistance offered to the transfer of heat.

Surface Conductance, symbol (f), is the amount of heat transferred by conduction, convection, and radiation between a surface and the air adjacent to it, per hour, per square foot, per degree Fahrenheit difference in temperature between the air and the surface. Symbol (f_i) indicates internal conditions, or still air, which averages 1·65 B.T.U., whilst (f_o) indicates external conditions, with an average wind velocity of 15 m.p.h. and a value of 6·00 B.T.U.

Air Space.—The thermal conductance of an air space is the amount of heat expressed in B.T.U. transmitted by conduction, convection, and radiation across an air space 1 square foot in area, in 1 hour, for 1° F. temperature difference between the enclosing surfaces. It varies with mean absolute temperature, width of the air space, and the position and character of the materials enclosing the air space, but it has been shown that for any air space over ¾ inch wide, faced with ordinary building materials, it may be taken for all practical purposes as a constant, namely 1·10, denoted by the symbol (a).

CONDUCTIVITY OF BUILDING MATERIALS

On page 87 is a list of recommended coefficients for building materials in common use, which will be found useful for purposes of comparison, and which will be used in subsequent calculations in this chapter for the purpose of calculating heat losses through various composite structures.

This table of recommended thermal coefficients can be used for calculating the thermal transmittance through most types of structure in

general use in this country. Ability to make such calculations is of considerable service in enabling one to select the best types of materials and methods of construction from the standpoint of heating costs—both capital cost of heating plant and fuel costs. A very simple method of making these calculations will be described.

THERMAL COEFFICIENTS AND RESISTANCES OF COMMON BUILDING MATERIALS

Materials.		k or C	Co-efficient	Resist-ance.
Air space, over ¾ inch thick		a	1·10	0·91
Surface coefficient, interior		f_i	1·65	0·61
Surface coefficient, exterior		f_o	6·00	0·17
Asbestos cement		k	2·70	0·37
Brick, common		k	5·00	0·20
Brick, face		k	9·20	0·11
Cement mortar		k	12·00	0·08
Cinder concrete		k	5·20	0·19
Concrete, typical		k	12·00	0·08
Glass		k	5·50	0·18
Glass wool		k	0·27	3·70
Plaster, gypsum, typical		k	3·30	0·30
Plaster, gypsum, on metal lath	Total thickness ¾ in.	C	4·40	0·23
Plaster, gypsum, on wood lath		C	2·50	0·40
Plaster, lime, on wood lath		C	2·00	0·50
Plaster board, ⅜ inch thick		C	3·73	0·27
[1] Roofing. asphalt		C	6·50	0·15
,, built-up, ⅜ inch thick		C	3·53	0·28
,, slate		k	10·37	0·10
,, tile		k	5·00	0·20
Sawdust and shavings		k	0·41	2·44
Stone, typical		k	12·50	0·08
Stucco		k	12·00	0·08
Tentest Fibre-board		k	0·38	2·63
Tile—typical hollow clay (4 inches)		C	1·00	1·00
Tile or Terrazzo—typical flooring		k	12·00	0·08
Wood—average used for construction		k	1·00	1·00

[1] Roofing, Metal—disregard conductivity of metal, using surface coefficients only. For corrugated metal add 50 per cent. to surface coefficient to allow for increase in area.

Thermal Transmittance includes Surface Coefficients.—First we must be quite clear as to the difference between the heat passing through a given thickness of material for a given temperature difference from face to face, and the heat which will pass through a structure embodying the same thickness of material for the same temperature difference from air to air.

In the table of thermal coefficients the figure (k) recommended for concrete is 12·00 (*i.e.* 12 B.T.U. will pass through 1 square foot of concrete 1 inch thick in 1 hour for 1° F. temperature difference from face to face), and the resistance is 0·08 (*i.e.* $\frac{1}{12}$). A greater thickness of the same material offers proportionately greater resistance to the passage of heat and the resistance of 5-inch concrete would therefore be $\frac{1}{12} \times 5 = 0{\cdot}416$. The conductance (C) of a 5-inch concrete block would therefore be $\frac{1}{{\cdot}416} = 2{\cdot}4$.

When, however, 5-inch concrete blocks are used for the construction of a wall, the wall offers greater resistance to the passage of heat than the internal resistance of the blocks themselves, because of the surface resistances (or air films) on each side of the wall. In calculating the thermal transmittance of structure these surface resistances must always be taken into account. In the case of an external wall of concrete 5 inches thick, we have to consider, therefore, the exterior surface coefficient and the interior surface coefficient as well as the concrete.

Calculation of Thermal Transmittance.—It is obvious that coefficients of conductivity can never be added together or subtracted one from the other, as this would mean that if a wall was increased in thickness by having a layer of any material added to it, its heat transmittance would increase also, which is absurd. An increase in the thickness of a wall increases its total thermal resistance by the thermal resistance of the thickness of material added to it. Therefore, in calculating the thermal transmittance of any structure we must first determine the thermal resistance of its component parts, add these together, and then find the reciprocal of the total resistance, which will be the thermal transmittance.

The thermal transmittance of an external wall of 5-inch concrete may, therefore, be calculated without complicated formulæ as follows:

Example 1

Material.	Coefficient.	Thickness.	Resistance.
Exterior surface	f_o 6·00	—	0·17
Concrete	k 12·00	5 inches	0·416
Interior surface	f_i 1·65	—	0·61
	Total resistance . .		1·196

$$\text{Thermal transmittance} = \frac{1}{1{\cdot}196} = 0{\cdot}83.$$

We see, therefore, that although the conductance of a 5-inch concrete block is 2·4, the thermal transmittance of the external wall which they compose is only 0·83 B.T.U. per square foot per hour, per degree Fahrenheit temperature difference from the air on one side of the wall to the air on the other side. When calculating the heat loss through the wall for a given set of conditions, the latter is obviously the figure to use.

For example, if the wall encloses a room in which the temperature of the air is 60° F., when the outside air temperature is 30° F. (*i.e.* a temperature difference of 30° F.), the amount of heat passing through each square foot of the wall will be 0·83 × 30 = 24·9 B.T.U. per hour. If the wall is 1,000 square feet in area, the heat transmitted through the wall will be 24·9 × 1,000 = 24,900 B.T.U. per hour.

Now suppose that ½-inch Tentest fibre-board is applied to the interior of this wall as permanent shuttering, *i.e.* bonded to the concrete. As

there is no air space, the calculation will be the same as before, with the addition of the correct resistance for ½-inch Tentest, *viz.* :

Example 2

Material.	Coefficient.	Thickness.	Resistance.
Exterior surface . . .	f_o 6·00	—	0·17
Concrete	k 12·00	5 inches	0·416
Tentest fibre-board. . .	k 0·38	½ inch	1·316
Interior surface . . .	f_i 1·65	—	0·61
	Total resistance . .		2·512

$$\text{Thermal transmittance} = \frac{1}{2{\cdot}512} = 0{\cdot}40.$$

With a temperature difference of 30° F. and a wall area of 1,000 square feet, the thermal transmittance through the wall will now be 0·40 × 1,000 × 30 = 12,000 B.T.U. per hour. The reduction of the heat transmission by more than half, although the thickness of the wall has been increased by only ½ inch, or 10 per cent., illustrates the effect of using a material of high thermal resistance, as compared with a material of low thermal resistance. To secure the same result with concrete alone, we should have had to increase the thickness of the wall by nearly 16 inches.

Effect of Air Space.—Now suppose that, instead of being bonded to the concrete itself, the Tentest is fixed to timber battens 1 inch thick, so that there is an air space of 1 inch between the concrete and the fibre-board, our calculation will be as follows :

Example 3

Material.	Coefficient.	Thickness.	Resistance.
Exterior surface . . .	f_o 6·00	—	0·17
Concrete	k 12·00	5 inches	0·416
Air space	a 1·10	1 inch	0·91
Tentest fibre-board. . .	k 0·38	½ inch	1·316
Interior surface . . .	f_i 1·65	—	0·61
	Total resistance . .		3·422

$$\text{Thermal transmittance} = \frac{1}{3{\cdot}422} = 0{\cdot}292.$$

Now the heat transmitted through 1,000 square feet of wall for 30° F. temperature difference will be 0·292 × 30 × 1,000 = 8,760 B.T.U.

The examples given are comparatively simple, embodying only two materials and an air space, but the same principle can be applied to calculating the thermal transmittance of any composite structure.

ROOFS

The thermal transmittance of flat roofs can be calculated as for walls in the foregoing.

With a pitched roof and a horizontal ceiling, the roof has a larger area than the ceiling. The larger area will obviously transmit more heat for any given temperature difference from inside to outside, and hence a lessened resistance to the transmission of heat. When calculating the thermal transmittance through this type of roof incorporating an unheated attic, the resistance of the attic air space (0·91) must be divided into separate resistances each equal to 0·455, one of which may be applied to the roof and one to the ceiling. We then calculate the resistance of the roof separately, correct it by a factor appropriate to its pitch, and add to the result the ceiling resistance, thus obtaining the total overall resistance for the combined roof and ceiling.

A list of correction factors is given below.

The application of the correction factor to a roof of 1-inch timber, covered with built-up roofing with a 30-degree pitch and a ceiling of ½-inch Tentest, is shown by the following example:

Example 4

Roof Resistance		Ceiling Resistance.	
Material.	Resistance.	Material.	Resistance.
Exterior coefficient	0·17	Interior coefficient	0·61
⅜-inch built-up roofing	0·28	½-inch Tentest	1·316
1-inch timber	1·00	½-inch air space	0·455
½ air space	0·455		
	1·905		2·381

$$\text{Roof resistance} = 1{\cdot}905 \times 0{\cdot}866 = 1{\cdot}649$$
$$\text{Ceiling resistance} = 2{\cdot}381$$
$$\text{Total resistance} = 4{\cdot}030$$
$$\text{Thermal transmittance} = \frac{1}{4{\cdot}030} = 0{\cdot}248$$

In the above calculation the two columns showing the "coefficient" and "thickness of material used" have been omitted. This can be done in practice when the method of calculation is clearly understood.

CORRECTION FACTORS FOR VARIOUS ROOF PITCHES

Pitch	1/6	1/4	30°	1/3	1/2	Gothic	1/1
Factor	·949	·894	·866	·833	·707	·500	·463

It should now be clear that there is a vast difference between a thermal coefficient (k), thermal conductance (C) and thermal transmittance (U)

and when figures from various manufacturers of materials are compared, care should be taken to see that only the figures of the same nature are compared, as otherwise confusion will result.

For much of the foregoing we are indebted to the Tentest Fibre-board Company's *Structural Insulation.*

SOUND INSULATION

The problem of noise tends to increase in intensity, and our tolerance of objectionable noise to become less.

Noises can be considered under the following headings:

1. Outdoor noises:
   (*a*) Traffic.
   (*b*) Noise generated in other buildings.
   (*c*) Special noise sources: *e.g.* from playing-fields, schools, railways.
2. Indoor noises:
   (*a*) Impact noise: *e.g.* footsteps on hard floorings.
   (*b*) Air-borne noise: *e.g.* conversation and radio.

Noise Transmission.—Noise may pass through the air in the form of air vibrations and will thus enter a room directly through gaps around doors and windows, ventilators, or other openings.

It may pass through a wall, floor, or other enclosing member by diaphragm action. This occurs when the enclosing member consists of relatively thin sheet material, which vibrates with the sound vibrations and so reproduces them on the other side. The diaphragm of a telephone receiver vibrates in this way in accordance with electro-magnetic variations acting upon it.

In thicker material, noise may be transmitted by wave motion within the material, though the thicker the material the weaker will be the wave motion given to the air on the opposite side.

The diaphragm action of a thin sheeting may increase the sound. This occurs when the vibration period of the sheeting coincides with the period of the sound waves. This coincident vibration is familiar in the form of audible vibration of furniture, windows, etc., when heavy traffic is passing.

Definitions.—Although a high degree of accuracy is not possible in calculating values for sound insulation, the simple theory of the subject is of value in understanding the nature of sound and insulation.

The *Decibel* is the unit of sound intensity. But as the loudness of sound to the human ear varies with the frequency of the sound, having a louder effect at higher frequencies for the same intensity, a unit of equivalent loudness, called the *Phon,* is used in assessing the loudness of sounds. Over an ordinary range of frequencies there is very little difference between the intensity of sound in decibels and its loudness in phons.

Although a difference of 1 decibel or phon can be detected by an acute human ear, a difference of 5 decibels or phons is about the minimum which is easily detected by the average human ear, and this should be

remembered when considering the significance of insulation in terms of phon reduction.

The average loudnesses of some common air-borne noises are :[1]

Noise.	Equivalent loudness in phons.
Loud wireless	80–90
Average wireless	65–80
Soft wireless	50–65
Normal conversation	up to 65
Quiet conversation	up to 45
Typing and tabulating—noisy office	up to 80

Suggested standards of quiet are :[1]

Occupancy.	Loudness in phons.
Study or sleeping	15
Reading or writing	20
Boardroom	30
Sedentary office work, quiet conversation	35
Average office, telephone work, and restaurant	40
Noisy office	60

[1] From *Post-war Building Studies, No. 14*, Ministry of Works.

It should be understood that what is reasonably required is a reduction of noise to a level which is not annoying. Complete sound-proofing is not practicable—nor would there be any object in it since absolute quiet is not called for.

Planning for Quiet.—Much can be done by planning to reduce noise reaching the rooms most in use and where quiet is particularly desired. In planning semi-detached houses and flats it is advisable to place the living-rooms away from the party wall. The kitchen and hall can be placed against the party wall and will thus act as insulating space. Upstairs, bathrooms and built-in wardrobes can be arranged along the party wall to insulate the bedrooms.

In office buildings and flats, corridors and store space can be arranged to insulate the principal rooms from noise sources.

An important point in planning is that it is more economical to prevent noise at the source than to prevent its passage by insulated construction.

Noise Prevention.—In houses and flats the worst noises are impact noises from footsteps on hard floorings and the air-borne noise of wireless sets.

Impact noises can be greatly reduced at the source by providing soft surfaces. Carpets on underfelt will prevent loud footstep noise, and if living-rooms are not placed against party walls the sound of wireless sets will not be a nuisance to neighbours as long as they are not turned up to an excessive level.

The problem of impact noises is greater in flats than in houses, and is aggravated in the cheaper flats by the general absence of carpets. Structural insulation is essential to reduce the passage of both impact and air-borne noises.

Methods of Insulation.—It is suggested that a party wall in domestic buildings should give a noise reduction of at least 55 decibels. The ordinary 9-inch brick party wall gives a reduction of about 50 decibels, which is not adequate.

Where the living-rooms of two houses adjoin, extra insulation is therefore needed in the party walls. One suitable method is to have the plaster or sheeted lining fixed to wood battens clear of the wall, the battens being secured to the wall with felt-lined clips. The floor, too, should be insulated, preferably by having a floating wood floor, by which is meant wood flooring on battens resting on felt or other soft material supported on the floor structure.

In flats, concrete floors $4\frac{1}{2}$ inches thick are common, and this thickness gives a noise reduction of about 45 decibels, which is not enough. A normal timber floor may not give even this amount of reduction. The floating floor construction described above may be expected to give an extra reduction of 10 decibels or more, according to the thickness of the insulating material.

It should be remembered that noises are transmitted from one room to another by vibration of the solid parts of the structure : walls, partitions, floors, and ceilings. In flats it is essential to completely insulate the whole room as a " box." The party-wall lining should be a separate partition with no ties connecting it with the wall, and it should rest on the floating floor. A false ceiling should be constructed with a space between ceiling and upper floor soffit, which in the case of concrete floors may be used to accommodate pipes.

A method of improving the insulation of party walls between houses is to build the wall in two $4\frac{1}{2}$-inch thicknesses with a cavity between. There should be no ties between the two leaves, except where necessary to give adequate strength. Where all outer walls are of the cavity type, a cavity party wall will make the walls of each house discontinuous one from another, and so greatly impede the passage of sound.

Frames and Pipes.—Noise is readily transmitted along steel and reinforced concrete framing members, and along metal pipes.

In framed flats, floors and walls should have resilient pads interposed between framing members and walls, partitions and floors. Floors should rest on padded bearings. Columns and girders should be wrapped with resilient material, so that they do not make direct contact with walls and other parts of the structure.

In factories, both column and machine foundations should be insulated from the floors, so that noise vibrations from machines cannot readily be transmitted through the framing to other parts of the building.

Typical Insulation Values.—The table on p. 94 shows noise-reduction values for materials in thicknesses commonly used and should be compared with the desirable noise reduction between rooms already mentioned.

As fibre-board is sometimes described as "insulation" board, it is interesting to notice that its sound-insulation value is not great, in fact not greater

than plaster. It is a good heat insulator, but has no wonderful properties as a sound insulator.

Construction.	Total thickness.	Average noise reduction in decibels.
PARTITIONS AND WALLS		
Fibre-board	½ inch	25
21-ounce window glass	– inch	28
Plate glass	¼ inch	30
Clinker block, plastered	2 inches	35
Brickwork	4½ inches	45
Brickwork	9 inches	50
Timber studding, lath and plaster, both sides	5¾ inches	50
FLOORS		
Timber joist floor, lath-and-plaster ceiling	—	45
Timber joist floor, plaster-board ceiling	—	35
Timber joist floor, lath-and-plaster ceiling, and floating floor (boards on battens on quilt)	—	55

Soft porous materials (examples: hair felt, glass wool, Cabot's quilt) are better insulators per unit mass than solid non-porous materials such as brickwork and concrete.

With soft porous materials the sound insulation increases directly with increase of thickness, so that doubling the thickness doubles the insulation or sound reduction.

With hard non-porous materials this does not apply, and the sound insulation is only slightly increased by doubling the thickness of the material. Thus, a $4\frac{1}{2}$-inch brick wall gives a sound reduction of 45 decibels, and a 9-inch brick wall a sound reduction of 50 decibels. There is thus only an extra sound reduction of 5 decibels for twice the thickness.

CHAPTER 6

PAINTING

PAINTING is both a decorative and a preservative process. It is broadly divisible into three classes: plain painting on new work, plain painting on old work, and decorative painting, this last being divisible into many sub-classes, ranging from the quite simple to fine-art mural decoration. Each type requires modified methods and the selection of appropriate materials, appropriate both to the method and to the ground to be painted. As regards this question of selection of materials, difficulties are rapidly diminishing with the advance made in scientific research, which has enabled manufacturers to prepare ready-mixed paints adapted to almost any conditions met with in normal building undertakings. The unexpected, however, constantly turns up, and so a knowledge of materials in their raw and made-up states is as necessary to the builder as it is to the operative painter and decorator. Successful mixing and application largely depend upon such knowledge.

MATERIALS

Paints are compounds, containing: (1) a base, usually white lead, red lead, or oxide of zinc; (2) a stain or a pigment, such as colouring earths, lampblack, metal oxides, etc.; (3) a vehicle, oil, turpentine, spirit, magilp, water, etc. (turpentine and spirits being classified as solvents); (4) driers, and (5) extenders, inert matters such as barytes, chalk, clay, etc.; (6) plastics, to increase durability.

Bases.—The "body" (opacity) and "covering" (spreading) properties of a paint largely depend upon the nature and quality of the base. In most cases when oil paints are used body is of great importance, and from this point of view lithopone, "genuine" white lead, zinc white, and the titanium paints come in the order given. On the other hand, while a hundredweight of white lead will cover from 500 to 750 square yards (according to the surface to be covered), an equal amount of zinc oxide will cover from 1,000 to 1,400 square yards; red oxide goes to 1,200 square yards, and red lead 560 to 590 square yards. The durability of a paint is largely a matter of the purity of the base, though it is also influenced by possible chemical reactions set up by the vehicles, driers, and stainers used; also the nature of the ground to be painted.

White Lead is the product of the corrosion of sheet lead. It is generally sold ground in oil, forming a paste containing from 6 to 9 per cent. of linseed oil. "Genuine" white lead is pure white lead, and it is illegal

to sell it as such if containing any other substance than the oil necessary to make it into a paste. " Reduced " white lead contains from 20 to 30 per cent. of some extender (usually barytes or chalk) for No. 1, and from 70 to 80 per cent. of extenders for No. 4. White lead should have a good colour, work smoothly and freely, be free from grit and skins, spread well, and have high concealing powers. It is easy to test a sample by slightly thinning with linseed oil and spreading on a piece of darkly veined board, using a medium soft brush. In this way a good paint can be easily distinguished from an inferior one. Reduced lead, especially if coarsely ground and made up with powerful driers, is apt to " chalk "—waste away quickly in powder as soon as the oil has oxidised. White lead will amalgamate with almost any pigment, taking on darker light tints, but not with those containing sulphur (such as ultramarine, sap green, yellow, and orange orpiment, King's yellow, antimony sulphide, Indian yellow, gamboge, iodine scarlet, cochineal, and carmine), which turn the paint dark yellow to black, just as sulphur in the air will do.

Basic Sulphate of Lead is used as a base chiefly for light-tinted paints, and gives very good results.

Zinc White is oxide of zinc , procurable as a powder or ground in linseed oil as a paste. It is non-poisonous, is brilliant white, has a good body with exceptional covering capacity, and can be tinted even more freely than white lead. In practice it is found that a mixture of 75 per cent. of white lead with 25 per cent. of zinc white, ground in pure linseed oil with a little pure turpentine, gives a better result than either paint alone. The zinc minimises the tendency to chalk and to discoloration from atmospheric influences. But an over coat of zinc white (or a paint containing zinc oxide), on an under coat of white lead soon discolours. The proper under coats for zinc white are zinc white, lithopone, or aluminium.

Lithopone is a compound of zinc sulphide, barium sulphate, with a trace of zinc oxide. It possesses good body and spreading power, is useful for indoor work, and makes an excellent under coat.

Flake White and *Chinese White*, pure, finely ground white lead ground in sweet oil, are pigments and bases used in preparing artists' colours, and are only used in high-class decoration.

Red Lead is made from yellow monoxide of lead. Mixed with oil it serves as a complete paint. It is also used as a base for certain dark paints and also as a stainer. It has a good body, adheres strongly, and resists damp, heat, and frost ; it therefore is largely used on iron, and thinned out as a priming coat on wood and plaster. It has much the same drying effects as litharge. Its one drawback is its heaviness, which makes mixing difficult, and necessitates its being well stirred and quickly brushed out when painting. It must not be mixed with, or be used as, a priming coat under paints containing sulphur.

Red Oxide is an oxide of iron. It has much the same qualities as red lead, but is brighter in hue.

Extenders, also called Fillers, must not be looked upon as adulterants. Though some of them are introduced as cheapeners, and may have poorer covering powers and elasticity than the bases, many are introduced to improve the paints in certain respects and for special purposes. That is the case, for instance, with paints containing casein, cement, or silver sand.

Barytes, finely ground heavy spar, is perhaps the most commonly used of extenders. It is very deficient in body, but its introduction into " reduced " white lead has the valuable property of resisting discoloration by sulphur. It is also useful in the preparation of Brunswick greens and the lake colours.

Chalk (calcium carbonate) is useful in preparing water paints, having a good body, but in oil paints the body is poor and its admixture is only permissible in small quantities to correct acidity of some pigments. In large quantities it destroys elasticity and adherence and promotes chalking. *Whiting* often replaces chalk, and has the same characteristics.

Gypsum, finely ground, improves the brilliance of white and also of Venetian red. It is one of the principal bases of distempers, valuable for its property of strong adherence.

Silica, and *Silver Sand*, in fine powder, are introduced in paints to give them heat- and fire-resisting properties, and to give them textures. Such paints are valuable for priming coats.

Asbestine, asbestos ground to a fine powder, or magnesium silicate, is used for the same purposes as silica. It also improves suspension of pigments.

White China Clay is sometimes an adulterant, but has the merit of increasing suspension of pigments in the vehicle. It is therefore introduced in most dipping paints.

Casein, prepared from the curd of milk, when mixed with chalk produces an insoluble, very hard-drying compound. It is used in the preparation of fire- and heat-resisting paints (for radiators, stoves, etc.). Casein and skim milk are also the chief ingredients in water paints.

Cement is introduced in the manufacture of both oil and water paints, with the aim of producing paints having a distinct texture, adhering strongly to wood, plaster, concrete, and giving the appearance of stone.

Stainers.—Staining pigments form a very diverse body of materials, and it will be only possible here to give a brief review of the characteristic types. White pigments have already been dealt with under bases.

Blacks of varying density are produced from burning ivory chips (only used for artists' colours), lampblack, gasblack (soot from burning oil, gas, etc., under special conditions and refining it). They will mix in water, oil, and varnish, serve as stainers, are permanent, and will resist acids, alkalis, oils, etc. Graphite paints are specially valuable for applying to metals. Greys are produced by staining white paints with blacks.

Reds have already been partly dealt with under red lead and red oxide. Indian red is a preparation of copperas or ferrous sulphate. It has a good body and is permanent on exposure to light. Only those with a high ferric-oxide content should be mixed with pure white lead. Venetian red is prepared either from a natural earth or by heating ferrous sulphate with lime. It possesses good body and permanency, particularly when protected by varnish. Vermilion, when prepared from sulphide of mercury and sulphur, has a brilliant hue and good body, but unless protected by hard varnish soon turns brown on exposure; but vermilions prepared from coal-tar bases are true " fast reds " and reliable stainers for producing delicate rose tints. Vermilionettes, prepared from coal-tar lakes, are brilliant in colour, but have the disadvantage of too readily dissolving in oil and turpentine; they therefore do not blend well, and when painted over " bleed " through the upper coat. When it is not possible to burn off the paint, it should have one or two coats of knotting, which will prevent the bleeding.

Blues.—Cobalt has a slight greenish hue. It is a good stainer, mixing well with other paints, setting up no chemical reactions, is fast to light, and is not influenced by lime, alkalis, or acids. There are two ultramarines, one made from lapis lazuli and used for artists' colours, the other a preparation of clay, sodium carbonate, and other ingredients. It has a reddish tinge, but when mixed with zinc oxide produces fine tints. It must not be mixed with white lead. It mixes in oil, water, and varnish, and is permanent to light. Prussian blue is derived from metal salts, is moderately permanent, mixes both in oil and water, but discolours in contact with lime and whiting.

Yellows.—Chrome yellows are produced from nitrate of lead and potassium bichromate, in a great many hues, from yellow and canary to orange. They have a good body, but are discoloured by sulphurous fumes. Cadmium, only serviceable for the highest class of decorative work, will mix with any vehicle and other pigment except those containing lead or copper. Naples yellow is an oxide of lead and antimony, with a rich range of permanent colours, but is improved by ochres and other colours containing iron. Ochres, both red and yellow, are natural earths, which will grind in oil or water. Burnt ochres (calcined) are darker in hue. Both raw and burnt sienna (natural earths) produce good yellows, fast to light.

Greens.—Terra verte (also known as " Verona green " and green ochre) is a natural earth of rather dull hue, but very durable. Chrome green when pure is remarkably permanent. Mixed with barytes it is known as " Brunswick green." Emerald green is a preparation of arsenious oxide and copper oxide, of a bright hue. It mixes well with all paints except those containing sulphur, is permanent, but has the disadvantage of being highly poisonous. It can be replaced by Viridian, an oxide of chromium, which is brilliant and permanent, though slightly yellowish.

Browns are mostly produced by raw or burnt umber and a darker

true natural earth known as Vandyke brown. They are all permanent and will mix in both oil and water.

Purple brown is derived from an iron oxide. When not overloaded with barytes, it has a good body, is permanent, and forms a serviceable cheap paint.

Vehicles.—Vehicles are also known as mediums, thinners, and, as regards turpentines, spirits, and a few others, solvents. The principal of these is linseed oil.

Linseed Oil when refined is limpid, almost colourless, with a slight yellowish tinge, while unfiltered is slightly turbid and of a brownish hue. By bleaching nearly every tinge of colour is removed, when it is suitable for very fine, light-tinted paints, and can even replace walnut and hemp-seed oil in mixing artists' colours. It mixes well with most pigments without altering their character, and possesses the valuable quality of drying (by oxidation) on exposure to air, thus leaving a homogeneous film of pigment behind. By boiling, when the oil thickens greatly, the drying properties are hastened. When a slow-drying paint is required, therefore, raw linseed oil is used, and when a quick-drying paint is needed boiled linseed oil is substituted. In very many cases a mixture of the two, varying in proportion as circumstances dictate, is used. As a rule priming coats are required to dry quicker than upper ones, so the dosing of oil is regulated accordingly. Almost invariably white lead and zinc oxide are ground in linseed oil to form a paste and then more linseed oil is added during the making up of paints or for thinning when using.

Tung, or *Chinese Wood Oil*, is derived from a nut, is of a pale yellow to brownish tinge, slightly viscous, and a fairly good substitute for linseed oil, but more suited for making up paints than for use as a subsequent thinner.

Soya Bean Oil is also a good medium with fair drying properties, much used in the manufacture of paints.

Turpentine is the refined sap of several varieties of pine trees. There is a notable difference between French, American, Russian (or Baltic), and Venice turpentine. French is excellent, but expensive and difficult to obtain; Russian has an evil smell and bad colour, usually containing tarry substances; Venice turpentine is highly refined, and only used in the best class of decorative work. American turpentine is almost colourless, and is largely used as a solvent for many pigments; it is a useful thinner and an excellent cleanser. There are various substitutes known as Patent Turpentine, Turpeens, etc., used in the manufacture of some paints. The best of these is White Spirit, a petroleum distillate, which is water white; it is fairly good, and has the advantage of not becoming viscous by keeping, but must not be mixed with bituminous or asphaltic paints, and is also unsatisfactory with cheap paints containing resins.

Spirits of various kinds are used both as solvents and thinners. They are the only perfect solvents for certain pigments and also for some of the gums used in varnishes, while they are also valued because when once the

paint or varnish has been spread the medium evaporates quickly. Methylated spirit is chiefly used in painting, consisting of a mixture of about 90 per cent. of alcohol, 10 per cent. of wood spirit and traces of petroleum spirit, and a pale aniline violet dye. It is much used as a thinner for varnishes and as a cleanser. Both wood naphtha (wood spirit or methyl alcohol) and coal-tar naphtha, colourless, highly volatile fluids, are used as solvents for oils, fats, resins, gums, and waxes. Acetic acid, another wood product, is used as a solvent for metallic oxides and in the manufacture of sugar of lead. Amyl acetate is a water-white, slowly vaporising fluid useful as a solvent for gum sandarac, gum dammar, and other resins. Acetone, another colourless fluid, is highly volatile, mixes with alcohol, water, and oil, and is an excellent solvent of fats, resins, and gums. Amyl acetate and ethyl acetate are the solvents principally used in the preparation of cellulose varnishes and paints, and are used as thinners for them.

Driers.—Driers are added to paints to hasten the evaporation of the mediums. They are sold both in paste and liquid forms. Linseed oil, and some others, when boiled acquire marked drying properties, and these are the safest to use when possible. More energetic agents are the commonly used litharge, red lead, lead acetate, and the manganese group. They act by increasing the absorption of oxygen and so hastening evaporation, drying, and hardening. But there is danger in overdoing the use of driers, as by causing too rapid evaporation the film of paint may not be given sufficient time to adhere and the compound may be broken up, resulting in a paint which will powder or flake off. A paint containing an excess of driers becomes " dead " and loses all elasticity. If it is absolutely necessary for a paint to dry within twenty-four hours it is far safer to use cellulose paints than excess of driers in ordinary oil paints. Finally, it may be said that driers are only helpful if used with the greatest caution, and should not be added to ready-mixed paints, particularly of the enamel type.

Enamels.—Enamel paints contain either varnish or specially treated raw linseed oil, turpentine, and japan gold size. They have excellent body, are easy, smooth working when flowed on like varnish, not brushed on, and very durable. Having considerable body, one coat on a good primer is generally sufficient. Most of them dry with a hard, highly glossy surface, but there are also flat enamels, drying with a smooth, dull finish, but otherwise possessing the same characteristics. Enamels should be stirred during use, and as a rule should not be thinned ; if this is necessary then only by the addition of a little pure turpentine. They are mostly used for interior work on a priming of zinc oxide, left white or slightly tinted to the same colour as the enamel, but several shades lower. The priming should have a flat finish. Where tinted enamel is applied over white enamel, the white enamel should be rubbed down.

Gritted Paint.—A number of oil and water paints are marketed which

are mixed with silica, silver sand, or cement. Such are, among many, "Tungcrete" and "Cementona." They are intended to give a rough to medium textural finish, often designed to represent sandstone, and may be used as primers and finishing coats. Though requiring attention, especially in the selection of appropriate brushes, they are as easy to apply as limewashes, are durable both for inside and outside work, are to some extent water-repelling, and do not induce dampness from condensation.

Plastic Paints.—Plastic paints, though generally intended to give a textural surface, do so on a different principle from the above-described gritted paints.

They are mostly ground in oil, though some are in powder form ready for mixing with water. They contain materials which make up the paints into thick, plastic pastes, applied with a flexible palette knife or a stiff brush. They are usually applied thickly, and can be finished with a sponge, a crumpled strip of canvas, or with modelling implements, so they lend themselves to varied decoration, especially when finished with partly wiped-off scumbling colours.

Cellulose Paints and Varnishes.—Nitro-cellulose paints, enamels, and varnishes have a base of cotton, wood pulp, or similar material treated with nitric acid, tinted with stainers, and dissolved in amyl acetate, ethyl acetate, or some other rapidly evaporated solvent. The addition of plasticisers, gums, and resins determines their quality as paints, enamels, or varnishes. The untinted varnish is generally termed "lacquer" or "clear lacquer," and is used as a finishing coat where desired. There are various processes of manufacture, which need not detain us, beyond stating that one type, known as liquid celluloid, prepared by adding camphor to cellulose (prepared wood pulp), is frequently prepared from the clippings and waste from cinema films and other celluloid manufacture. This, though cheap, is too rapid in drying, leaving a thin film of paint, so that three-coat work is necessary when using it. An easily applied test quickly reveals whether the material has a nitro-cellulose or a celluloid base. A little of the material is placed in a tin and carefully warmed (it is very inflammable) to drive off the solvent. The residue, while still warm, if celluloid will give off an odour of camphor. These paints and varnishes require to be kept tightly sealed and applied rapidly, as we shall see presently when dealing with operations.

Bitumistic and Asphaltic Paints.—Bitumistic and asphaltic paints are useful for applying to protect walls from damp where colour, black and browns, is no objection, but particularly for painting metals, especially iron and steel. If these are clean, free from rust and grease, usually one application, without use of priming, will suffice.

Tar and Pitch.—Coal, wood, and petroleum tar is a cheap form of "paint" for wood and iron, but has the disadvantage of partly liquefying when exposed to heat—for instance, strong sunshine. Pitch—tar from

which more of the liquid has been removed—is rather more difficult to apply, but is more stable. Both tar and pitch are used in certain black paints and also stove and similar enamels and lacquers.

Distempers and Water Paints.—Ordinary distempers are mixtures of whiting or chalk with staining pigments and size. Water paints or washable distempers are more complicated compounds which are manufactured in three forms: (1) supplied as a liquid or a paste to which special petrifying liquid is added just before use; (2) a paste thinned by the addition of water; (3) powders which are mixed either with cold or hot water according to their type. By adding size to ordinary distempers the tendency to rub off is overcome or much reduced. Washable distempers or water paints must be allowed about four weeks before they can be washed; after three months or a little longer they can be scrubbed, that is to say, if the ground has been properly prepared.

Limewash.—Limewash is very useful for many purposes, such as for use on cellar-walls, outhouses, workshops and factories, stables and cow-houses. It is simply prepared by mixing slaked lime or chalk in water. The wash may be tinted by adding ochre, umber, or other suitable colouring matter. A little sugar dissolved in the whitewash improves adhesive proportions. Adhesion is also improved by adding common salt or size. Limewash can be applied to plaster, brick, stone or wood. A good wash for outside work, even for use on slate roofs, is made by preparing a paste of 7 pounds of freshly slaked lime, 2 pounds of plaster of Paris, 1 pound of oxide of zinc mixed with a little water. This is dissolved as required in half a gallon of water in which 1 pound of dextrine, 2 ounces of common salt, and 1 ounce of alum have been dissolved.

Lime-proof Colours.—The following colouring matters are not affected when used with lime: White—barytes white, gypsum, zinc white. Red—vermilions, light red, Venetian red, Indian red, madder lakes. Orange—cadmium, orange chrome, Mars orange, burnt sienna, burnt Roman ochre, light red. Yellow—aureolin, cadmium yellow, lemon yellow, Naples yellow, Mars yellow, raw sienna, yellow ochre, Roman ochre, transparent gold ochre, brown ochre, Indian yellow, Oxford yellow. Green—oxide of chromium, transparent oxide of chromium, viridian, emerald green, malachite green, verdigris, terre verte, cobalt green, chrome green. Blue—pure ultramarine, artificial ultramarine, new blue, permanent blue, cobalt blue, cerulean blue, smalt. Purple—purple madder, Mars violet. Brown—bone brown, bistre, Prussian brown, burnt umber, Vienna brown, Vandyke brown, Cologne earth, asphaltum, Cassel earth, manganese brown. Citrine—raw umber, Mars brown. Black—ivory black, lampblack, blue black, charcoal black, cork black, Indian ink, blacklead, drop black, plumbago.

Stability of Pigments.—To the above list of pigments uninfluenced by lime, the following data as to the stability of pigments under varying

conditions will be found a useful guide. Pigments liable to discoloration under the influence of sulphuretted hydrogen, impure air, and moisture, which should not be mixed with paints containing sulphur: White—chemnitz white, plate white, white lead. Yellow—chrome yellow, mineral yellow, Naples yellow. Red—red lead, purple red, iodine scarlet. Green—verdigris, Scheele's green, emerald green, mountain green. Blue—Prussian blue, Antwerp blue. Orange—orange chrome. Pigments only slightly affected by above conditions: White—zinc oxide, constant white, titanium whites. Red—vermilion, red ochre, Indian red, madder lakes. Yellow—yellow ochre, barium chromide, zinc chromate, aureolin, raw sienna. Green—chrome green, cobalt green. Blue—ultramarine, smalt. Brown—Vandyke brown, raw umber, burnt umber, manganese brown, sepia. Orange—orange vermilion, burnt sienna. Black—ivory black, lampblack, Indian ink, graphite. Pigments which are damaged on contact with white lead, chrome, and other lead paints. Red—Iodine scarlet, cochineal, carmine. Yellow—yellow orpiment, King's yellow, Indian yellow, gamboge. Orange—golden antimony, sulphide, orange orpiment. Green—sap green. Blue—ultramarine. Pigments which will withstand heat (suitable for radiators, stoves, etc.): White—titanium white, barium white, zinc white. Red—red ochre, Venetian red, Indian red. Yellow—Naples yellow, antimony yellow. Blue—smalt, ultramarine, royal blue. Green—chrome green, cobalt green. Orange—burnt sienna, burnt ochre. Brown—burnt umber, manganese brown. Black—graphite, mineral black.

Varnishes.—Varnishes for practical purposes may be defined as gums or resins, or gums and resins, in a dissolved state. For the painter and decorator they are divisible into two broad classes: (1) oil varnishes, and (2) spirit varnishes. They may be water white, naturally or artificially coloured, and are used as protective coats for paper, wood, or paint. They are also mixed with paints in the manufacture of enamels. Most varnishes dry with a medium or high gloss, but there are also flatting varnishes which dry with a matt finish. These latter are distinct from rubbing varnishes, which are used as under coats, and may be rubbed down to receive a second coat. A very large number of resins and many gums are used in making varnishes, sometimes a mixture of two or more. Copal and lac are the most commonly used. It is essential to exercise care in the selection of varnishes for different purposes, and some hints on this will be given when we come to deal with the processes of varnishing.

Knotting.—Knotting is a spirit shellac varnish, made by dissolving shellac in methylated spirit or in naphtha or a mixture of the two. "Patent" Knotting is made up of 40 pounds of orange shellac, 8 gallons of spirit, and $\frac{1}{3}$ pound of oxalic acid. Knotting is chiefly used for painting over, in one or two very thin coats, knots in wood, or all over very resinous wood, to prevent the resin working through and spoiling the paint or other surface decorations. It is also the best priming coat over a badly stained ceiling, acting as an effectual stopping.

Size.—Size is another priming liquid made with diluted glue and a little alum. The best is made from concentrated size, a high-class glue prepared in powder or jelly form, ready to be dissolved in hot water. It acts as a stopping on paper, wood, or plaster. On wood, besides filling pores, it counteracts any sap present, and on plaster neutralises free lime. Size is added to limewashes in order to increase adhesion and durability. Gold size, used in decoration, is gum animé dissolved in hot linseed oil, to which, on cooling, turpentine and litharge are added.

Stains.—Stains are of many kinds. There is, for instance, the simple solution of permanganate of potash in water for staining floors, or the highly valuable chemical preservatives, such as creosote or the well-known "Solignum," which is a translucent stain either colourless or tinted, applicable to woodwork of any kind. There are also water stains (aniline or other colouring matters dissolved in water); spirit stains, in which the medium quickly co-operates; and oil stains, or thin scumbling paints. The outstanding difference between paints and stains is that paints leave a compact protective film, while stains merely colour, and partly fill the pores of wood, without actually concealing the texture and figuring of the wood. Oil stains are used in decoration as scumbling colours over paint or plaster, acting as thin, semi-transparent washes.

Paint Removers.—Where burning off is impossible or not desirable, chemical paint removers are available. These are of two classes: (1) alkaline paint removers, and (2) spirituous paint removers. The first are usually composed of caustic soda or slaked lime, or a mixture of the two with some inert substance, such as starch, whiting, or china clay. The alkali saponifies the oil in the paint, causes it to soften, when it is easily removed. The drawback to these is that the alkali is apt to impregnate the wood or plaster and later works through any new paint or varnish, often damaging it seriously. The best remedy against this is prompt removal of the softened paint and then washing down with warm water acidulated with vinegar, which will "kill" the alkali. The acidulated solution is rinsed off after a few minutes with clear warm water. This must be done thoroughly to be effective. The second class depends upon the action of fusel oil, acetone, or some other agent for softening the old paints; they are less violent, and can be more easily removed. For instance, with one of these it is possible to soften and remove varnish without disturbing the paint below, or the top coat of paint, leaving the under coat untouched. They are, therefore, safer in general use. For cleaning dirty paint sugar soap is excellent. This substance is also effective in softening and removing old varnished paper.

MIXING PAINTS

A paint shop need not be elaborately equipped. The chief requisites are a range of shelves and cupboards for the storage of stock, a mixing bench, paint mill and paint mixer, and a number of strainers. The bench should be of stout timber, about 2 feet 6 inches long, 1 foot 6 inches

wide, and standing 2 feet 9 inches high; if with a shelf below, so much the better. On this should be one or two fair-sized slabs of marble or slate, with stone or glass mullers for mixing small quantities of paint. The paint mill is a moderate-sized funnel-shaped vessel, containing curved paddles or beaters which are revolved by a hand-wheel, and fitted with a tap for emptying. It is very useful for thinning overstiff paints, and also for grinding coarse paint. A mixing machine is a rather more complicated affair, usually a circular vessel containing arms or knives which break up the paint and mix it intimately with the oil or other thinners. They are made to deal with from ½ a gallon upwards, and can be operated by hand or power. There are many kinds of strainers. The most commonly used have tapering sides and movable gauze bottoms. Some have ring bottoms which permit of either gauze or muslin being used. For finer work and big quantities an iron stand is made to hold two or three large strainers, one above the other. The mesh of the strainer varies from coarse to fine from top downwards. This multiple and graduated straining saves time, and produces better results. Straining is an essential part in the preparation of paint, so there should be a sufficiency of them, reserved if possible for oil paints and distempers. They should be cleaned immediately after use, by gentle scraping off of superfluous paint and then washing in hot water and soap. If done at once this is quite as efficacious as using turpentine, and of course, far cheaper. The implements needed will be various forms and sizes of palette knives, a wooden or iron paint mixer, not unlike a butter hand used in dairies for shaping pats of butter, but an iron one with perforated blade. There must also be a set of brushes for testing the brushing or spreading properties of the mixed paints. It will also be well always to have handy odds and ends of planks and a few sheets of glass on which paint can be spread for testing purposes, especially in the matching of tints and shades.

Unless ready-mixed paints are used, one of the great troubles of preparing successive batches of paint is to ensure exact identity of shade. With ready-made paint the lowering of tone is an easy matter, as usually instructions are given as to how much white lead or zinc white should be added to obtain a desired tint. But with shop-mixed paint the matter is rather more difficult and troublesome. Unless a perfectly standardised paint, with exact proportions decided to produce a definite tint, is being used, the mix should be as near as possible in a batch sufficient to complete the job. Where this is not possible brushing out on sheets of glass, in strips close to each other, will afford the best means for matching. The secrets to successful mixing are fine grinding, thorough working, and efficient straining. Straining following working up on the slab or in the mill not only removes coarse material, but helps greatly in securing intimate mixing.

The common bases in colour mixing are white lead and zinc oxide, which usually reach the paint shop in the form of a paste resembling

putty. The first thing to be done is to break it down with more linseed oil. This should be done gradually, by putting the paste on the slab or in a pail, or in the mill, adding a little oil and working up either with the muller and palette knife, or the mixing paddle. When this has been taken up more oil is added and the mixing carried on. This is followed by adding turpentine, driers, and stainers, finally more oil to obtain the desired consistency. It is better, however, to add the driers only at the last minute, as this tends to keep the paint more fluid and easy working. Occasional brushing-out tests are advisable. When completely mixed set aside for twenty-four hours; it will then be quite ready for straining and use. Coarse pieces and skins can often be worked up for rough paints.

PREPARATION OF SURFACES

Careful preparation of surfaces to be painted is necessary, because it is essential to really good work, and also leads to economy of time, labour, and materials. Such preparation will vary according to the nature and condition of the ground and also the type of material to be used, as a rough limewash, distemper, and oil paint will each call for a different treatment. In any case, however, it is necessary to have a clean surface, free from grease, dust, and loose pieces. Grease, on no matter what kind of ground, will prevent proper adhesion, and is always likely to work its way through and stain the paint. It also retards drying. Therefore, the preliminary work must be brushing down and where needed washing.

Taking grounds in their natural order as met with in building operations, we first come to walls, which may be of bare brick or stone, plastered or concrete.

Brickwork, if it is to be painted, should be freed from dust and the jointing made good. If there are any signs of efflorescence, the white stains must be wiped or washed off. If the brickwork is new, it will be wise, after thorough washing, to give time for the work to dry and so give an opportunity for the salts in the bricks or mortar to come to the surface. In bad cases, or where time does not allow of delay, after washing down with acidulated water, the whole surface should be dressed with a petrifying liquid, which is intended to stop efflorescence and serve as a priming coat. There are many of these petrifying liquids on the market, such as are used for plaster and concrete. It is flowed on freely, but must leave the surface rough. Where dampness is feared, an under coat of red lead is a good precaution, and can be followed on by any other paint. Stone can be treated in the same way, especially those of a soft lime.

With plaster and concrete the principal disturbing element is the free lime present, which is apt to make its way to the surface and through the paint, greatly affecting it. If the paint dries with a hard skin and the efflorescence is unable to make its way through, it may detach the paint from the wall, causing it to bulge and then to scale off or powder, while with a softer, slower-drying paint the oil in its composition is saponified and the chemical combination of the paint is disturbed before the film

has time to form, and so is broken up. This can in some cases be overcome by a priming, in others by applying a " sharp " coat, containing more turpentine than oil. The safest way, of course, when possible is to give sufficient time for the plaster or concrete to mature ; but that will require three, six, or twelve months and even after that will stand in need of a corrective priming. We shall come to details presently.

For wood the first need is cleaning, then according to the nature of the wood some filling. This is more specially needed on softwoods, and old wood which has been neglected, as these are more or less porous and the priming is to avoid suction. New wood and resinous wood will often contain sap or resin, which prevents paint adhering firmly, and also is apt to stain or otherwise damage it. Such woods require a priming coat of knotting. Knotting, in two or more coats, must also be painted over knots and all resin pockets after these have been emptied and then stopped with putty or some wood paste, such as " Necol." A much-favoured priming for new wood is a thin coat of red lead, which is easily applied and quite effective.

APPLYING PAINTS

Painting on Wood.—Factory-made woodwork is mostly delivered after having received a priming coat generally of red lead mixed with white lead and liberally thinned. It will usually require rubbing down and stopping. The object of the priming coat is to provide a paint which will sink into the wood, stop the suction, and provide a good key for the next coat. It is therefore desirable that the wood should be well seasoned before the priming coat is applied, otherwise the sap, not having dried out, will prevent sufficient penetration, while the paint will not adhere strongly. The priming coat must be thin, with a liberal amount of oil to assist penetration, but with very absorbent wood the suction may be so powerful that the oil is withdrawn from the pigment, and then there will be imperfect adherence, with bad result on the subsequent coats. Sap also has a bad influence on the priming, so when the wood is very soft, open-pored, or still slightly sappy, it is well to size the work before applying the priming. Size is prepared by soaking glue in sufficient cold water to cover it. When quite soft and fully swollen it is placed on a stove and slowly raised to a temperature of about 150° Fahr., when 5 gallons of hot water, in which 1 pound of alum has been dissolved, are added and stirred in. Red lead is not absolutely necessary in a priming coat, and should not be used beneath enamel, as it is liable to work through. Here are two useful recipes for priming paints : (1) white lead in paste, 21 pounds ; red lead, dry, 1 pound ; raw linseed oil, $3\frac{1}{2}$ pints; turpentine, 1 pint ; patent driers, 12 ounces. The red lead may be left out and the driers increased to about 14 ounces. (2) white lead paste, 100 pounds ; raw linseed oil, 31 pounds ; turpentine, $14\frac{1}{2}$ pounds ; liquid driers, 1 pound. With very absorbent wood it may be necessary to thin with a little more oil and turpentine, two-thirds of the first to one-third of the

second. Priming, especially when drying with a semi-gloss, must be rubbed down. This is done with rottenstone and water.

The next process is stopping. When the wood is faulty, being unequal, cracked, or having knot-holes, etc., it is levelled up by means of fillers. These may consist of special compositions, such as " Necol " and other wood pulps dissolved in a highly volatile medium, which quickly evaporates, leaving a hard, strongly adhering substance ; or a paste. Here are three recipes for wood fillers : (1) mix 2 pounds of pulverised pumice stone, 2 pounds of corn starch, 1 gill of shellac varnish with about a pint of boiled linseed oil, to make into a workable paste. This may be thinned with turpentine. (2) Mix 5 pounds of corn starch, 3 ounces of carbonate of magnesium, 1 quart of shiny japan with 1 quart of linseed oil. (3) Mix 50 pounds of barytes, 6 ounces of brown soap, 1 ounce of borax with 2 pints of linseed oil, 2 pints of liquid driers, 2 pints of turpentine, and 2 pints of water. The stopping is applied with a palette knife, pressed well home, and smoothed with fine glasspaper. If this stopping was applied before sizing and priming, the oil or other medium would be drawn out of the pillar, which would then crumble away. Stopping of this kind and knots should receive two or more coats of knotting. Loose knots, by the way, should either be glued in or removed and the holes stopped either with wood filler, wood pulp, or a plug of wood. Knotting, as already explained, is a stiff shellac varnish ; more rarely red lead knotting is used. Knotting should be brushed on firmly in very thin coats, one after the other. If applied thick it will dry in ridges, requiring to be rubbed down and giving very insecure protection. In some cases thinned-down knotting is applied all over sappy wood, but this is not advisable, and is somewhat too expensive.

After priming and stopping the surface is ready for the second coat. It may here be pointed out that almost without exception it is a bad practice to apply thick coats of paint. A thick coat will dry badly and unequally, the surface hardening before the under part, and then cracks appear and the whole film decays. The hardening of paints is due to oxidisation of the oil, driers being added to hasten the absorption of oxygen from the air. In a thick coat, therefore, the surface is oxidised, dried, and the absorption of oxygen prevented or retarded. With thin coats there is more even drying and stronger adherence. That is why two-coat work is better than one-coat work, and three-coat than two-coat. The desired thickness of film is secured with even surface and good adherence. The first or priming coat is a filler, providing an anchorage and a key for the upper coat. It must, on wood, be reasonably thin and well brushed in. The second coat provides substance, and the third adds substance and furnishes protection against atmospheric influences and also rubbing. Three-coat and four-coat work are far more durable than two-coat work, and when well done stand cleaning better ; while when repainting becomes necessary, frequently merely thorough rubbing down of the finishing coat and a new finishing coat will be satisfactory.

The second coat should follow on when the priming is dry, but still fresh. It should not be too quick drying, and should not, as a rule, be of the enamel or glossy-surface type, unless a thin, delicate finishing coat is to be applied, when an enamel is excellent. When dry it should be rubbed down with pumice stone and water, partly in order to obtain a perfectly smooth surface, partly to roughen it with a view to give a key to the next coat. Each coat should be allowed to dry and be rubbed down before receiving another coat, but should be still fresh. Some softwoods, and some hardwoods, such as oak, need elastic paints, which do not contain barytes or chalk as extenders, and do not dry too hard. When wood shrinks or "works" it is apt to crack the film of hard-drying paints.

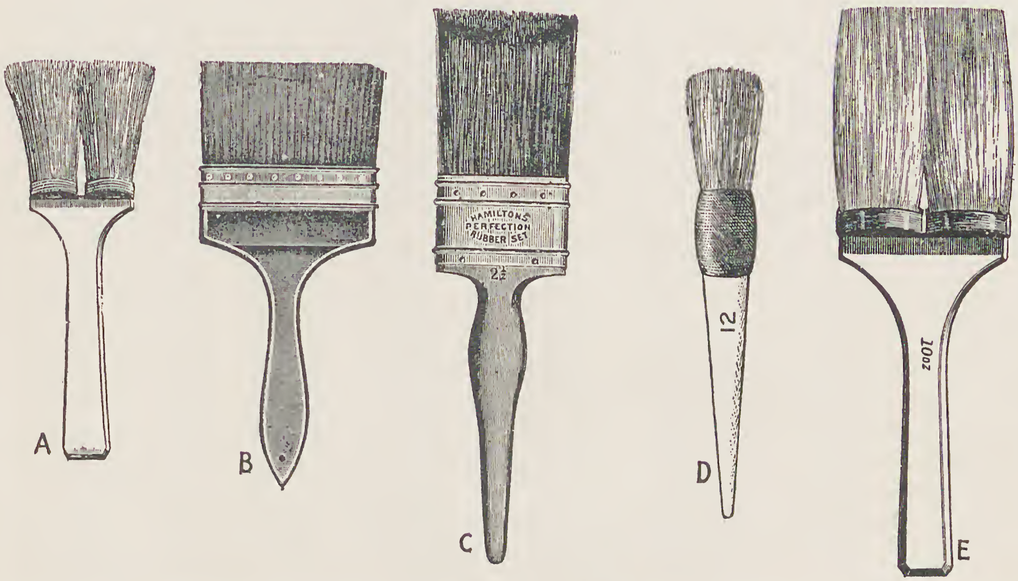


Fig. 106.—A. Washing-down brush. B. Wall brush. C. Bevelled varnish brush. D. Sash tool. E. Distemper brush.

Top coats should be slower drying than those beneath to permit of free oxidising throughout the mass.

Painting on old woodwork varies considerably, according to the condition of the paint and the wood itself. If the paint is merely dirty and surface worn, but the under coat is good, all that will be needed is thorough rubbing down with glasspaper and the application of a top or finishing coat. But if cracked or blistered all the paint should be removed, either by burning off or by softening with chemical paint removers and scraping off. In using the painter's torch great care must be taken not to damage the wood, particularly mouldings or other carved parts. Charred wood gives a poor surface, and will have to be made good with stopping. As already explained, chemical stripping must be quickly followed by a neutralising wash and rinsing. Both alkali and

acid are bad for paint. The priming and stopping will depend upon the condition of the wood. Wood fillers are often required, and considerable stopping of damaged parts is frequently needed. Decayed wood should be cut out and replaced. No amount of priming and painting will arrest decay; it will go on beneath the paint film and probably contaminate adjacent wood. Occasionally worm-eaten wood has to be dealt with; if still solid, but more or less riddled with worm holes, it can be treated with a mixture of equal quantities of turpentine and paraffin oil. This must be got into the holes somehow or other. A clean large paint brush dipped into the mixture will do for treating horizontal surfaces, but for vertical ones, such as panels, a fountain-pen filler or other form of small squirt will be needed. It is a long, tedious process, but as a rule in such cases expense is a secondary consideration. It should be remembered that this treatment will be ineffective unless the mixture penetrates well into the holes. Joints and mitres should also be treated with the mixture. Three or four days after the treatment the holes can be filled with the following stopping: mix 1 part of beeswax, 3 parts of paraffin wax with 8 parts of turpentine containing 10 per cent. of paraffin oil. Press in well, and after two or three days, when the stopping will have shrunk, make good with more of the paste, when dry cover with knotting and the wood will be ready for painting or staining.

A trouble met with in some hardwoods is patchiness of finish owing to unevenness of suction in different parts of the wood. This must be overcome by adapting the priming to the case. Some light is thrown on the subject by F. L. Brown and C. E. Hrubesky in their *Indian Engineering Chemistry*. They state that tests prove that sapwood density and width of annual rings have a marked influence on the adhesion and durability of paint. The denser the wood and the narrower the rings, the more enduring will be the paint when applied. The question of density is, of course, only another way of stating that soft, porous woods demand special treatment, as they rob the paint prematurely of its oil; but the observation as to annual rings, though tending to the same conclusion, is new, and suggests new lines of research.

Painting on Brick and Stone.—New brickwork should be allowed at least six months to dry out before being made ready for painting. By that time trouble from efflorescence should have been overcome. If still present a wash of dilute hydrochloric acid can be applied. A good priming coat can be made up with Venetian red ground in oil and thinned with raw linseed oil, a small quantity of liquid driers and terebene. When dry any other oil colour can be applied. Usually those drying with a glossy surface are preferred, as they are washed down by rain and can be easily cleaned. In old brickwork difficulty may arise, soft and hard bricks being found in the same façade, or perhaps decayed bricks, the difference of suction causing patchiness. This usually shows up on the priming coat, and then the patches over soft brick should be gone over with an oily paint to procure uniformity, when the second coat can be applied.

Pointing also requires attention. If the brickwork has been previously limewashed, as much as possible of the old wash must be got off by hard brushing and washing down. This should be followed by a priming of red lead with white lead. The finishing coat, to dry glossy, should be made up with linseed oil only, no turpentine or driers. On the other hand, if a brick finish is desired (when painting over with oil colours a decayed brick façade as a preservative measure), the oil should be reduced as much as possible and powdered brick incorporated in the paint. When dry it will only be necessary to line off with a straightedge and lining brush to produce the effect of pointing, which may be either white (two parts white lead, one part oxide of zinc) or black (graphite or mineral black).

Silicate paint can be applied directly to bricks, though preferably over a wash of petrifying liquid on old bricks, whether the bricks be dry or wet. Bituminous paints are also applied to remedy dampness ; but they must be applied to dry bricks. If the dark colours are objected to a cement wash or limewash can be used as a top coat if washed on while the bituminous paint is soft. This finish also prevents the paint running when heated by sunshine.

Colour washes for brickwork are made with a liquid grout of cement or slaked lime to which a little sand or crushed brick is added with earth colours or oxides for tinting. A durable wash is made by melting 4 ounces of brown glue in a gluepot in a gallon of water, and adding while hot 1 pound of alum. As soon as it is cold it can be tinted with Venetian red, Spanish brown, or yellow ochre. A durable limewash tested by the Building Research Station is made up by placing a basket of good quicklime in a barrel with 20 pounds of tallow ; sufficient hot water is poured over to slake the lime, the barrel being covered with a sack until the slaking is complete. This can be diluted as required, and if desired may be tinted by adding suitable dry colouring material. Limewashes should be applied with broad, long-haired brushes, but if not too gritty can also be sprayed on, a method to be preferred when dealing with rough, uneven surfaces.

Stone does not require very different treatment, but limestones and sandstones should have a priming coat of rather oily paint ; harder stones require a "sharp" paint. If limestone shows signs of decay it should be brushed down vigorously, the pointing made good, and then receive a priming of petrifying liquid. The best finish for stone is one of the gritty paints imitating stone, though in some positions, such as the lower storey of a town house, a hard glossy finish is more durable. Paint is often an efficient protection for stone, both against weather and abrasion, but it cannot be regarded as a lasting cure when once decay has set in.

Painting on Plaster and Concrete.—The painting of these materials accounts for by far the greater number of troubles and failures. These are because they take long to dry out, that a certain amount of free lime

they contain is soluble, and that they are alkaline. Now, no ordinary paint will adhere thoroughly to a wet or really damp surface, as water is repellent to oil and turpentine, and therefore there is mechanical interference. On the other hand, paint is attacked by free lime and alkalinity, mostly by the saponification of the oil, which disintegrates the paint. Lime and alkali also bleach the majority of pigments. If we consider plasters we find that they fall into three main classes : (1) lime putty and sand plasters, more or less porous ; (2) hard plasters, including the low burnt types, plaster of Paris and pink plasters, and the hard burnt plasters, such as Keene's, Parian, and most of the proprietary articles, which have a gypsum base ; (3) cements, such as Portland and Roman cements, which are mixtures of lime and clay, quick setting, and strongly alkaline. Concrete is a conglomerate of 1 or 2 with coarse aggregates. The trouble with lime plasters arises from their being slow drying and containing much free lime. With the gypsum plasters troubles are generally due to their quick, hard setting, which prevents a sufficient key being obtained for the paint. Cements and concretes, though quick setting, are slow drying, so the chemical difficulties are accentuated. If sufficient time could be allowed for the materials to dry out thoroughly, painting difficulties would soon be overcome. But lime plasters require weeks to dry out; even hard plasters, though they harden quickly, retain moisture for at least three weeks ; cement and concrete take many months. In this last case the matter is made worse because it is necessary to keep the surface wet for some days in order to ensure perfect maturing. Therefore the first difficulty to be considered is that of moisture. Neither oil paint nor distemper will adhere to a really wet surface. They may stick temporarily to a damp one, but if we seal up with paint water and salts will work out to the surface and push off the paint in blisters, flakes, or powder. A water paint has a better chance because it is porous ; it may be stained, but will adhere better. With a comparatively thin coat of plaster on lathing, with a more or less absorbent backing of brick or stone, the difficulty is lessened, because the mixture will evaporate from the back, and so on such a surface painting can be undertaken earlier than on plaster as a solid concrete backing, or on a ground which is sealed on both sides. Dr. A. H. Gardner, an American paint expert, has provided us with a convenient test for gauging the wetness of plaster. If 1 gramme of phenol phthalein is dissolved in 99 grammes of absolute alcohol and kept in a phial with a drop stopper, one or two drops of the solution applied to the plastered wall will quickly reveal its condition in two essential particulars, for if damp the dissolved alkali reacting on the solution will turn it pink ; if the plaster is dry the drops of the solution will remain colourless. The rapidity with which the drops turn pink is a measure of the dampness and alkalinity of the plaster.

If the fresh plaster or concrete contains a marked quantity of free lime a neutralising liquid should be applied. Perhaps the best of these is

made by dissolving 2 or 3 pounds of zinc sulphate crystals in a gallon of water. This should be flowed on freely, followed in extreme cases with a primary coat of high-grade 2 parts white lead to 1 part zinc oxide flat paint thinned with tung oil. Then should follow two or three coats of good paint, either oil or one of the prepared cement paints. For the interior white high gloss or eggshell (semi-matt) paint makes a good finish. This is also useful where high luminosity is desired, as such paints reflect light.

Dr. Gardner, already referred to, recommends for general use high-class flat paints of the order containing a high pigment concentration, a relatively small percentage of oil and gum, and a substantial percentage of volatile thinners, such as turpentine or mineral spirits. If such paints are properly thinned on the priming coat they almost invariably give satisfaction, producing a pleasing, semi-matt, washable, and sanitary surface. His own old laboratories were so treated immediately after construction, and stood well for over ten years without showing any trace of scaling, peeling, or other defects. In his new laboratories the walls were painted within ten days of laying the plaster. The walls were first treated with the zinc-sulphate solution, followed by the application of a high-grade sanitary flat wall paint reduced in the proportion of 1 quart of boiled linseed oil to a gallon of paint. Although in some rooms of this laboratory the walls were subjected during the daytime to steam and slightly acid vapours, and other trying conditions, nevertheless no defects were developed.

Hard-drying plasters, even Keene's, differ considerably, if not in composition, in preparation and behaviour, so it is well to experiment with a known brand or brands and adapt painting procedure accordingly. But the usual course with such plasters as Keene's and Sirapite is to follow on with the painting immediately after the laying, when it has partly set but not hardened. The paint is mixed "sharp," but with sufficient oil to make it work smoothly and prevent too rapid drying, and this is applied just as soon as the plaster can bear the pressure of the brush. By this means the paint film forms part of the plaster composition, and under such circumstances blistering, scaling, and rapid powdering are rare. Some of those plasters, however, require more oil than others, and in some cases it is better to allow two or three weeks to elapse and then use a good washable water paint as a priming coat.

Concrete generally speaking is more porous, if not absorbent, than plaster, and so both the neutralising wash and the priming coat are of especial importance. Much will depend upon the effects aimed at. If the concrete is to receive two or three coats of full-bodied colours, whether with a matt or glossy finish, then the neutralising wash of zinc sulphate must be followed with a fairly "sharp" white lead-zinc oxide priming coat. It is better, in such cases, if possible, to apply a suitable distemper, which can be washed off after three months or so, to be replaced by the lead-zinc priming coat. This gives an opportunity for the concrete to

sweat out both excess moisture and salts, and after that the oil painting will be more permanent. When, however, it is desired to leave the texture of the concrete apparent, then coloured cement washes should be used. The finely ground pigment is mixed with dry cement and then water is added. For such a process only a limited number of colouring agents are available. For white, a white cement is the most satisfactory; for black, either carbon black or black oxide of manganese; for reds, Venetian red, red hæmatite, red ochre; for yellows, burnt umber or yellow ochre (to be used sparingly, as it attacks the upper layers of concrete); for green, ultramarine. There are also specially prepared paints for concrete on the market.

Much trouble is often met with in painting old plaster surfaces, especially when these have undergone repair at different times. Such surfaces usually are found to vary in suction, as probably several kinds of plaster have been used in patching. The first steps to be taken are to clean the surface thoroughly, level up, and then apply a coat of knotting over all. This will generally prove a satisfactory preliminary wash for the priming coat. Old limewash, whether on plaster or concrete, should always be washed and scraped off, particularly if to be followed by oil paints.

Stucco is treated like other plaster work, but where keeping down expenses is necessary a satisfactory job can be made by applying two coats of water paint thinned with petrifying liquid to be finished by a finishing coat of oil paint, either semi-matt or glossy.

Asbestos-cement boards and sheets are strongly alkaline, and require liberal washes of the zinc-sulphate solution; they should be thoroughly wetted. This should be followed by an oil priming coat. There are several brands on the market for this purpose. After twenty-four hours an enamel under-coating is applied, which is to be rubbed down and followed by a finishing coat of matt enamel or glossy enamel for corridors, bathrooms, etc. Where such boards are not kept in place by wood fillets, but have been nailed down and butt jointed, the joints should be covered with strips of linen glued on. A more secure result, however, is obtained if the joints are stopped with whiting ground in oil, painted over with goldsize, over which 2-inch strips of muslin coated with goldsize are stuck.

Influence of Materials on Paint Films.—Extensive investigations on the influence of building materials on paint films have been carried out by the Building Research Station, and a Bulletin on the subject has been issued. It is pointed out that blistering, peeling, and flaking are due mainly to physical or mechanical causes, while softening (tackiness or stickiness) and bleaching (discoloration) to chemical action are brought about by the material with which the paint comes into contact. These experiments deal chiefly with plaster, cement rendering, and asbestos sheets, not with wood. Ultimately moisture in the material is the principal cause of failures with oil paints and to a lesser degree with water

FIG. 107.—BLISTERING—THE CAUSES ARE MOISTURE, "FATTY" UNDERCOATS, EXPOSURE TO HEAT WHILE DRYING, HEAVY APPLICATION OF PAINT.

(Courtesy of I.C.I. Paints Division.)

FIG. 108.—CRACKING—THE CAUSES ARE UNSEASONED TIMBER AND RATHER BRITTLE PAINT.

FIG. 109.—CHECKING OR FINE CRAZING—THE CAUSES ARE SOFT UNDERCOATS IN THIN PAINT FILM OR OVER-RAPID DRYING OF SOME TYPES OF HARD GLOSS PAINT.

(Both photos by courtesy of I.C.I. Paints Division.)

paints. The commonly accepted rule, that concrete and cement rendering should be allowed as long as possible to mature before painting, is found to be sound as regards moisture. The moisture evaporated from material of this kind is often sufficient to cause blistering in its efforts to escape. The same result may come from capillary moisture, due to the absence of a damp-proof course or as a result of a leak from above. Another point is that an oily film adheres less readily to a damp than to a dry surface. On the other hand, water paints, being more or less porous, adhere better. But this no longer holds true if the surface is treated with a priming coat, and this is seldom strong enough to prevent hydrostatic pressure, which would cause the paint to disintegrate together with the priming coat. Water should not be allowed behind the paint film, more especially if both sides of the board are treated. In practice it is found safer, at all events for some months, to leave one side of plastered or rendered surfaces and building boards unpainted. For temporary work, distemper should be used, to be followed after a year by oil paints.

As regards soluble salts in the building material, these may affect the paints both physically and chemically. Efflorescence, for instance, due to moisture dissolving the salts in the materials which crystallise on the surface, if not able to escape, may cause the paint to blister and peel, while on distempers the crystals often cause discoloration. Efflorescence can only be cured by thorough drying out, though the process of drying can be hastened by washing with weak acid solutions and brushing off the crystals. The chemical action of these crystals is also powerful. It is held by the Research Station that too much emphasis is laid on the action of free lime in the plaster or cement, because if free lime comes into contact with linseed oil, an insoluble soap is formed which generally protects the remainder of the paint film. But if soda or potash salts are present, soluble soaps are formed by amalgamation with the oil, and these are easily washed off. An invaluable fact brought out is that tung oil, or Chinese wood oil, is far less subject to attack than linseed oil. It would appear that a cement quite free from alkalis can safely be painted on even if wet. High calcium limes are usually quite or nearly free from alkalis, and are therefore safe.

Bleaching is due to caustic alkalis, though there are certain ranges of "lime-fast" pigments. Prussian blue, chrome pigments, and also some organic pigments are very sensitive, and for this reason it is suggested that a little Prussian blue in linseed oil forms a good test as to the inert character of the concrete or cement rendered surface. For initial decoration such surfaces, including asbestos sheets, it is suggested should be painted with ordinary distemper or better still casein distemper (which is not affected by alkalis).

Finally, we may sum up in the words of the report: "The chief safeguards which can be adopted in painting surfaces which are likely to be chemically destructive is to allow the material first to dry completely. The time required for this varies considerably according to differences of

situation and the conditions of drying, and is often a matter of months. It is usually considered unsafe to paint on Portland cement in less than a year. Even under good conditions evaporation is slow, on account of the dense nature of this material. Initial decoration may be carried out in a medium, such as casein distemper, which is not effected by alkalis. If the material has already partially dried, a washable distemper having a tung-oil basis can often be safely used for temporary decoration, provided that it contains only inert pigments. The use of various priming solutions or petrifying liquids to neutralise alkalis in cement and plaster has often been recommended, but these cannot be regarded as effective substitutes for thorough drying, although they may be useful as final safeguards on surfaces which are only faintly alkaline. Solutions of zinc sulphate or magnesium silico-fluoride have been used for this purpose, but there is a danger with these of subsequent trouble arising on account of efflorescence. Satisfactory results have been obtained in such materials as asbestos-cement sheets by applying a special inert priming paint before decorating in the ordinary way. Several such paints are now on the market, many of which have a tung oil-resin basis. Their effect is to insulate the linseed oil paint film from the destructive agents in the material."

Painting on Metals.—The first requisite with metal, especially iron and steel, is to have it perfectly clean, free from scale, rust, or grease. If already painted and the paint shows signs of decay it should be removed. For priming coats red lead, chromate of lead, iron oxide, graphite, and bitumistic paints are the best. When well applied more decorative paints may follow. White and very light paints should not follow on red lead; a full-bodied under coat in such cases is necessary. Boiled linseed oil is preferable for the priming coat, without driers. Iron oxide, it should be stated, is readily soluble in linseed, so rust stains, after being thoroughly cleaned off, should receive a thin coating of shellac knotting in which a little red lead has been mixed, before the priming coat is applied. The knotting should cover the stained part, going well beyond the edges. Aluminium paint is a good medium, does well on well-cleaned iron or steel, a single coat usually being sufficient; but much depends upon the fineness of grinding, as coarse grinding provides a poor protective film. Aluminium is little affected by atmosphere, even by sea air.

In painting radiators and heating panels several points have to be kept in view. The paint must not be rendered brittle by heat so that it will scale off; it must not be discoloured by heat; and it must be applied in thin coats, so as not to detract from radiation. Paints ready made up for radiator and stove painting are on the market, and usually contain a staining varnish. Ordinary varnish and excess of driers tend to brittleness under heat. Aluminium paint provides a good priming coat and also a finish. As regards colour, white lead should not be used; but zinc white, lithopone, and titanium white (this best in combination with zinc oxide or lithopone) will not discolour in oil from heat. All pigments con-

taining iron should be discarded. Before painting it is well to clean off factory priming by applying coal-tar naphtha or benzole with a stiff brush. Then heat up and make good any defects from leakage. Aluminium paint should be applied on a warm radiator or heating panel. Then cool down and apply a thin coat of paint. Heat up slowly to hasten drying. Cool down and apply another coat, quite thin. For copper pipes one or two thin coats of glossy elastic enamel are best. It is advisable when possible to do the painting by means of a small spraying appliance, as it is easier to ensure thorough covering.

Galvanised iron will not take oil paint, which quickly peels off. The sheets should be lightly scratched with a wire brush or rubbed down with No. 2 sandpaper, washed down with soapy water, rinsed, and when dry receive a coat of water paint. This will provide a sound key for oil paint. Goldsize thinned in turpentine also makes a satisfactory priming.

Tarred Surfaces.—If a tarred surface has to be painted apply benzole, and when the tar has softened scrape off. When dry, apply a coat of patent knotting. If vestiges of tar still remain, give two coats. The surface is then ready for painting in the usual way.

ALUMINIUM PAINTS

Aluminium paints possess many merits; they have good covering powers, are not easily tarnished, withstand weather and sea air well, adhere strongly to metal, are excellent as primers, often acting as a brilliant foil under white or very pale pigments, and have a decorative value. Much, however, depends upon the fineness to which the metal flakes are reduced. Large flakes are apt to settle in the medium, thereby causing a great deal of trouble. These paints are made up in three types: for outside work, for interiors, and for applying to radiators, stoves, etc., the last being made up with a stoving varnish, so that heat converts them into a kind of japan. Although a good grade of aluminium paint can be applied with a brush, it does better when sprayed on, provided sufficient air pressure is maintained to keep the aluminium thoroughly in suspension. Aluminium, besides making a good primer by itself, is very useful when mixed with some other priming paint. For this purpose from 10 to 20 per cent. of aluminium in powder should be added to a white pigment ground in linseed oil with a little goldsize drier, and thinned either with white spirit or turpentine, or ready-mixed aluminium paint in about the same proportion can be added to the white paint. In either case the tone of the white paint is lowered, becoming slightly grey. While specially good on metal it does equally well on wood and plaster, and is also applicable to paper.

APPLYING CELLULOSE PAINTS AND VARNISHES

The composition of cellulose, or nitro-cellulose, paints and varnishes has already been described. Their particular merit under certain con-

ditions is the exceptionally rapid way in which they dry, leaving within a very short time a film firm enough to be painted upon. So marked is this, that three, and even four coats with a clear varnish finish can be applied on the same day. But this class of material has its advantages, even when such speed is not necessary. At first these paints and varnishes were applied only by spraying, but slightly slower, freer-working brushing-on cellulose paints and varnishes are now made. When using these materials quite as much care must be taken with the preparation of surfaces as under ordinary circumstances ; indeed, rather more, as they are applied in very thin films and will not stand much brushwork. The surfaces must be clean, dry, free from dust, grease, and oil. For plaster an oil-bound water paint makes a good primer, care being taken that all pinholes are well filled. Wood should receive the usual priming coat, knots and stopped resin pockets, etc., receiving a coat of pale knotting. Hardwoods should receive a priming coat with an oil base, which should be rubbed down. Oval brushes are better than flat ones, and they should be glue-set, as rubber-set ones soon go to pieces on account of the nitro-cellulose attacking the rubber. Both paints and varnishes must be brushed on quickly but lightly ; brushing out and stippling are impossible. A constant flowing process must be adopted. However, if wrinkles form they can be smoothed down with a special reducing liquid which is supplied with the paints. Rubbing down is also permissible. One coat may follow quickly on another, but it is well to allow an hour and a half to elapse between each application, particularly when there are more than two coats. Although surface hardening is so rapid, chemical changes go on underneath for some time, and by brushing on another coat too soon the skin may be softened, when the under coat is inevitably pulled up, and then cleaning off is the only possible remedy. As a rule an hour and half interval in warm and two hours in cold weather is ample. With spraying on the interval can be shortened considerably. The paints and varnish must be laid on in very thin coats. With light-tinted paints and enamels three coats are advisable, even when to be followed by two coats of cellulose varnish. With dark colours two coats will usually be found sufficient.

Owing to the extreme volatile nature of the mediums it is necessary to keep the containers tightly closed. Even then the paints and varnish may thicken, becoming difficult to apply. They should be thinned with an appropriate medium—that which has been used in the mixing of the paint or varnish. As a rule not more than 10 per cent. should be added.

Spraying on of cellulose paints and varnishes is advisable where large surfaces, or surfaces broken up by mouldings, etc., have to be covered. By this means there is much saving of time with greater certainty of even results. Either a high-pressure or a low-pressure machine can be used, but as there is less loss from " spraymist " with the latter, it is to be preferred, at all events for interior work. Steadiness of pressure must be kept during spraying, which must be continuous, the spraying nozzle

being kept fairly close to the surface to prevent loss and undue hastening of drying.

DISTEMPERING

The application of ordinary distemper and washable water paints does not differ. In both cases the best results are obtained when the weather is neither too hot and dry nor cold and damp ; this is because they must be brushed on freely and continuously, so that there should be no drying of edges with bad " laps," and no running of the colours. With ordinary distempers there must be only one coat with no touching up. If patchy or streaky it must be washed off and a fresh coat applied. With water paints two coats are permissible, though rarely necessary if the surface has been properly prepared. Wood after cleaning and making level, if very open and absorbent, should receive a wash of size, defects being stopped in the usual way. Then should follow a coat of claircole, made up by mixing $\frac{1}{2}$ pound of concentrated size of good glue with double the quantity of whiting and a little alum in a gallon of water. Plaster may need a neutralising wash, such as already described, and is then ready for the claircole. If, however, the plaster is old patched work, the patches should be given two coats of clear knotting before claircoling. In the case of patched and badly stained ceilings, after cleaning and applying two coats of knotting to the affected parts, the whole should receive a priming of flat white oil paint. This will give a good key for the distemper and prevent the stains working through. The form of brush is immaterial, providing it is reasonably soft and will carry well. Painting must be done with a full brush, the tip of the brush being used to swing over the work in any direction, but without crossing, stippling, etc. Most operatives find it convenient to cover the surface in strips of from 12 inches to 18 inches broad, but taking care to keep the edges " alive " to prevent bad, that is dark, " laps." When dry the distempered surface can be decorated by panel lines, stencilling, etc., in differently coloured distemper or oil paints. With water paints such decoration should be carried out before it is hard dry.

Poorly finished plastered surfaces can have lining paper (white for light tints, brown for dark ones) pasted over to receive the distemper. This method is very useful for temporary decoration on new plaster which is to be permanently finished six months or a year later.

It may be well to mention here the best way to remove old distemper, water paint, or limewash. This can usually be done easily enough with hot water containing a large dose of vinegar. This softens the material, which can then be scraped off. The surface should be finally rinsed with clear warm or cold water to remove its acid.

STAINING

The process of staining wood will differ according to the object in view. If creosote or a proprietary article, such as " Solignum," is being used at

once as a stain and a protective, then the material should be applied to the cleaned, dry wood, because the aim here is to secure deep penetration. The material must be used freely so that it shall sink in. If, on the other hand, ordinary oil, spirit, or water stains are being used solely for colouring purposes, then too great penetration will weaken the depth of tint, and to prevent this the wood should receive two or three coats of size according to the porosity of the wood. Oil stain can be applied to plaster, which should be first primed with a very thin coat of oil-bound white-lead-zinc-oxide or lithopone pigment, and allowed to dry thoroughly without leaving a sealing film.

VARNISHING

Varnishes are much more delicate materials than paint, and therefore require careful handling. It must be remembered, too, that spirit varnishes soon thicken and harden quickly. Only small quantities of varnish at a time should be poured out from their containers into cans for use, and poured not directly into the can, but against the sides and gently, otherwise bubbles of air will form which are difficult to work out. The varnish must be flowed, not brushed on, and this is best secured by dipping the tip of the brush in the varnish and drawing across, beginning from the top and working downwards. Care must be taken not to allow running, tears, or hardened edges. A warm, even temperature is the best, but it is absolutely necessary to exclude draught and avoid dust. If varnish is to be applied to a glossy surface it must be rubbed down, and if the surface is very hard it is well to wash down the surface with a little Fuller's earth dissolved in water. If two or more coats of varnish are applied, each under coat should be rubbed down when dry before another is applied. In some fine decorative work, such as lacquering, six or more coats may be necessary before the final glossy finish is flowed on. As already mentioned, apart from flat and glossy, clear and opaque, colourless and tinted, there are many types of varnishes, and the right one must be selected for the work in hand. For use on plain unpainted wood, especially pitch pine with its resin, and teak with its natural oil, pure bleached shellac spirit varnish is best applied in two coats. A different class comprise the spirit stains—methylated spirit, shellac, and stain. For rubbing and under coating a varnish which will flow out level, dry quickly with a surface not easily softened, remaining elastic rather than brittle, is needed. For a high glossy finish on decorative work not subject to hard wear a quick-drying varnish, with hard surface, even if brittle, is best. For use on paper a good copal varnish should be chosen. This can be applied directly on sanitary wall-papers, those printed in oil colours. Other types of paper, being porous, must first receive two coats of size, brushed out gently with a soft brush not to damage the design. When a varnish has to withstand great heat an oil varnish containing hardly any driers is necessary. This will dry slowly, but retain elasticity. A similar varnish, but thinned with turpentine, is indicated for refrigerators

or in positions subject to extreme cold. In such cases it is very necessary to keep the coat quite thin. For use on outdoor work, a slow-drying varnish with hard surface of the elastic type gives the best chance of durability, and these are mostly oil varnishes thinned with turpentine. If the varnishing has to be done in inclement weather, a harder, quicker-drying type must be used.

For mixing with " sharp colour " or ready-mixed paints special " mixing varnishes " are on the market. This is done to give the paint greater body and an enamel character. Some painters prefer to make their own mixture, and many varnishes are suitable for the purpose. On this subject an expert says: " In any paint mixtures containing raw or boiled oil there is a distinct limitation of the individual varnish which may be used for mixing purposes, and in order to determine very obvious unsuitability about an ounce of the varnish should be mixed with its own volume of boiled or raw oil. If on standing for a few hours there is any distinct 'curdling' or 'throwing out,' the varnish is not suitable for mixing with paints containing any appreciable amount of oil. Boiled oil, on mixing with many types of varnish, causes distinct cloudiness to develop on standing or even shortly after mixing. This may not be a bar to its use for paint mixing, and a practical test is to leave the boiled oil and varnish mixture for a few hours and then well brush out a film of it on a smooth surface. If it dries to a film free from clots or seediness, it is suitable. The other point to be decided is whether the varnish will react with any active ingredients in the actual paint mixture to be made. If the mixture itself turns solid or 'livers' on standing for some hours, the varnish is obviously not suitable. If the varnish mixes without appreciable thickening of the paint mixture taking place on standing, it may still be not fully compatible, and the paint when applied looks 'sleepy' and lacks gloss and flow. To determine if the varnish is really suitable for admixture with pigments take a quantity of paste white lead in oil and very gradually reduce it to a smooth thick cream, thoroughly stirring in very small additions of the varnish to be tested. Finally reduce down to thin paint consistency by adding more of the varnish, then strain the mixture through coarse muslin to eliminate any skin or soft unmixed lumps. This fluid paint should stand overnight without appreciable thickening up, and a coat of it applied to a clean metal surface should dry with a good gloss. Very decided thickening, or a soapy, 'sleepy' appearance of the test, when brushed out and dried, indicates that the varnish is not suitable for mixing with pigments in general."

Another word of warning is necessary, and that is, it is very bad policy to mix two kinds of varnish together, at least without careful practical tests.

PAINT SPRAYING

Painting by spraying is mostly adopted as a means for economising time and labour and is therefore reserved for big jobs, but the method is

not solely suitable for plain work, special sprayers being very largely used for the most elaborate decorative work.

The most simple type of mechanical painter consists of a closed vessel, a pail, or a tank on wheels, with a hand pump and a length of rubber tubing with nozzle at the end. These are still used for limewashing. The limewash is placed in the closed vessel and forced out through tube and nozzle by air pressure forced in by the hand pump. This method certainly saves time and labour ; it also often does away with the need for scaffolding and ensures the wash being propelled with considerable force and evenly spread. These are considerable advantages when white-washing or colour-washing factories, stables, warehouses, etc., especially on rough walls. If the vessel is not too large the air pressure usually prevents settlement of pigment, the spraying saving material. Some of these machines are fitted with foot pumps.

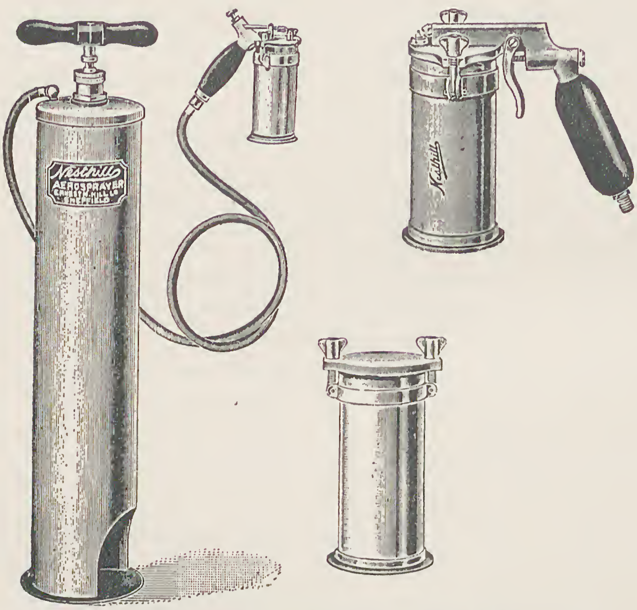


Fig. 110.—Hand sprayer with steel tank and brass pump.

Modern paint-spraying machines are more elaborate and efficient affairs. There are many types, divisible into two classes : (1) high-pressure system, (2) low-pressure machines. A high-pressure plant consists of an air-compressor with motor to drive it, a compressed-air reservoir, air purifier, rubber hose with paint-spraying pistol, and air conveying hose and a paint-container. On the smaller appliances this paint container is attached to the sprayer or pistol ; in the larger it is a pressure pot or tank. Most compressors for such plant will maintain a constant pressure of 60 pounds to the square inch, so that a pressure of 50 pounds per square inch can be delivered to the pistol. The compressed air passes into the tank, which contains an air purifier. This is a metal cylinder fitted with baffle plates or absorbent packing, which effectually removes dust and moisture from the air, these passing to a sump fitted with a drainage cock. It is necessary to remove dust and moisture from the air, otherwise they would be delivered to the pistol and forced on to the work and so spoil it. Attached to the air purifier is a rubber hose, which may be of any reasonable length, with the sprayer or pistol at the other end. This

sprayer must be light in weight to ensure ease in handling, simple enough for thorough routine cleaning, so constructed as to ensure perfect and very fine atomisation, and efficient control. It has a two-way entrance, one fitted to the compressed-air hose, the other to the paint-hose. Air and paint are delivered simultaneously in the body of the pistol, the compressed air impinging on the paint, so breaking it or atomising and expelling it through the nozzle as a very fine mist. As the pressure is 50 pounds to the square inch, the force with which the mist of paint strikes the surface is great, and this is an advantage in most cases. With the low-pressure system a much less powerful compressor and motor are used, and the paint is projected in a much softer way. The consequence is there is less " spray mist " or " fog," in other words, less atomised paint distributed in the air, though this is also governed to some extent by the distance between the nozzle and the surface being painted. When work is to be finished with two- or three-colour effects, protection has to be provided against overspray, and this also applies to mirrors or other adjacent surfaces. For this purpose marking paper and marking brushing on compound are provided. The marking paper is specially gummed paper which can be applied without fear of damage. The marking brushing-on compound is a non-drying, non-staining substance, easily applied and easily removed ; it is not acted upon by solvents in cellulose paints. In other cases, sheets are used to protect from spray. When properly used, however, the spraying machine really minimises waste of material.

Most paints can be economically used in these machines, but they should be finely ground, and some may require thinning, though this must not be overdone, and need not with the high-pressure system. When a gloss paint is difficult to deal with by this method, it may be made workable by the addition of from 5 per cent. to 7½ per cent. of turpentine. This should be tested by exposing such a thinned mixture in an open pot overnight. If it " bodies up," slightly jellifies, the mixture can be used in the spraying machine ; if not, it had better be rejected for that purpose. Water paints of some kinds are a little difficult to spray successfully. They can be greatly improved by the addition of a little thin jellified size, or some boiled starch. It is to be remembered that these spraying machines do best with full-bodied paints, which is one reason why cellulose paints and varnishes spray so well. For paints which are liable to settle, such as aluminium spirit paints, high pressure and a large nozzle are advisable. For most decorative work, fine-ground, high-grade paints are mostly used, and with these less pressure is quite as effective ; but for blended colour cloud effects thorough atomising is essential. There is, however, little difficulty in finding the right paints for the method, as most of them are adapted, or adaptable, to it. A little observation makes adjustment possible, and this also applies to the handling of the machine, particularly the control of pressure and attempt to apply too heavy coats at one operation.

As regards economy it is possible to spray an oil paint on a good surface at the rate of just over 76 square yards per hour, a black varnish on corrugated iron roofing at the rate of 129 square yards per hour, while a civic corporation found that they could spray their promenade shelters, railings, and lamp standards in 17 hours as against 78 hours for previous brush painting. On the other hand, in decorative work an expert, lecturing before the Incorporated Institute of British Decorators, said: " An operator with a spray gun will often do in an hour a piece of work, such as shading, blending, and clouding, that would take two or three brush hands several hours to complete. The greatest advantage that decorative spraying offers is that effect can be built up as the work is done with only one mixing of colour, and the operator can return to any point whilst the job is in progress and build it up still further, if necessary, by simple manipulation of the trigger of the gun. Another important advantage of the spray gun on this class of work is that the operator is not so near to the surface as when brushing, and he can, therefore, see exactly what he is doing."

QUANTITIES

It is commonly reckoned that 5 pounds of white lead, 5 pounds of putty, and 1 quart of oil will be required for stopping and first coat, and 5 pounds of white lead and 1 quart of oil for subsequent coats. This applies to general work on wood or plaster. The late A. S. Jennings, joint author of *The Modern Painter and Decorator*, gave, from experimental data, the following more detailed figures: ready-mixed paint in oil per gallon, first coat on wood or plaster, 50–55 square yards; second coat, 60–65 square yards; third or finishing coat, 75–85 square yards. Ready-mixed paints in turpentine, when used on an oil coat, 1 gallon per 85–90 square yards. Under coating ready for use: ordinary flatting type, 1 gallon, 85–90 square yards. Paste under-coats, thinned with turpentine (7 pounds of paint in 1½ pints of turpentine), 1 gallon will cover from 35–40 square yards. Varnish: easy-bodied type, 1 gallon will cover from 90–100 square yards; full-bodied type, 85–90 square yards. Enamel paints: easy-bodied type covers 75–80 square yards; full-bodied type, 70–75 square yards. Water paints: 7 pounds (reduced) on bare plaster, 30–35 square yards. Amount of materials for covering 400 square yards of iron or zinc: lead—first coat 66 pounds 10 ounces, and same weight for each subsequent coat; driers—first coat 4 pounds 3 ounces, second coat 4 pounds 3 ounces, third coat 6 pounds 4 ounces; oil—first coat ½ gallon 1 gill, second coat 1 gallon 1½ gills, third coat 2 gallons 3 gills; turpentine—first coat 1½ gallons, second coat 1 gallon 1½ gills, third coat ½ gallon ¾ gill.

CHAPTER 7

DECORATION

DECORATION in connection with private houses may mean far more than mere painting, and in the case of public buildings it nearly always goes much beyond that. It is not, however, intended in this book to deal with the more elaborate schemes, with its many complications calling for the assistance of experts. Here we shall only be intimately concerned with such work as falls within the average experience of builders. Thus, the fine art of mural painting merely concerns us in so far as it touches upon preparation of surfaces and a general knowledge of methods and styles, as these react on surrounding details which are necessary to make up a complete whole.

A semblance of simplicity is one of the guiding principles of the day in building and decoration. But even with the most modernistic type of building, such as the plain concrete-slab cube dwelling, or the palatial newspaper offices in reinforced concrete with interior and exterior walls faced with toughened glass in white metal framing, there is a considerable amount of diversified decoration. Perhaps the outstanding modern tendency in house decoration is the greater attention being paid to wall texture as distinct from mere coloration. That often involves the use of new materials and new methods, opening up possibilities for the development of individual skill and the display of taste.

PRINCIPLES OF DECORATION

The aim in decoration is, of course, to beautify, but that must be qualified by considerations of comfort, so that different rules necessarily apply to the home, where repose is a chief object, and the ceremony rooms of a public building, whether it be a church, an assembly hall, or a theatre. In other words, there must be harmony between the clothing and the structure of a building, a harmony which must extend to the furniture and purposes of the building or room. For practical reasons, too, the necessity of protection and preservation cannot be ignored. Mr. William Harvey, in a lecture on " Structure and Colour," delivered before the Royal Institute of British Architects, well says : " Structural honesty, combined with appropriate colour, should be kept in view in all architectural design, but it would be absurd to suppose that buildings are made merely to express true principles of structure and colour. It is only when the general purpose, the convenience, and economy of the

building have been considered that these aspects of architecture begin to loom large in the field of vision. However the architect faces his problem, colour and structure will take their place in the finished building. . . . Over and above the possibilities inherent in the selection of sound building materials of pleasant colour is the possibility of decoration by colour in the form of applied pigment, or by incrustation with marble, tiles, mosaic, or metal." Metal and ceramics, by the way, lead us to include glass, which is very important in present-day practice. It will thus be seen that "decoration" has a wide meaning, embracing, as it does, structural parts and materials. Pigments and wall-papers do not constitute the beginning and end of decoration, but colour is an essential part thereof, and so a study of the nature of colour is the first step necessary.

THE NATURE OF COLOUR

The science of colour is based on light which appears white, but if passed through a prism is split up and produces the solar spectrum, which is much the same as the colours seen in a rainbow. Commencing from left to right we have blue, yellow, and red showing prominently ; these are the Primaries. To the left of the blue are violet and blue violet ; between blue and yellow, blue green, green, and yellow green ; between yellow and red, yellow orange, orange, and red orange ; to the right of red, red violet and violet. These are the Secondaries. In terms of pigment we have to add white and black. Mixtures of the Primaries and Secondaries, with the addition of white and sometimes black, give an indefinite number of tints and shades. While mixtures of the Secondaries, possibly with the addition of white and black, give the Tertiary colours, which again give an indefinite number of tints and shades. The characteristics of the Primaries are that they are strong, bright, vivid, standing out boldly. The Secondaries are light, toning down to very soft tints, merging ultimately into slightly tinted white. They are, mostly, lighting up and retiring colours. The Tertiaries are dull, merging into browns and black. White, reds, and yellows are light-reflecting colours ; blues, greens, and black are light-absorbing colours. In practice, however, texture and surface condition have a very large influence in these matters. A polished surface reflects more light, and therefore will "light up" a room more than a matt or dull one. Thus a ceiling with whitewash will reflect about 75–80 per cent. of light, one covered with a flat white oil paint between 85–90, and one with a full-gloss white paint as much as 95 per cent., but a ceiling or wall painted with the brilliant but greyish-hued aluminium will reflect not more than 55–65 per cent. according to condition. Again, black velvet will reflect only 4 per cent. of light, but black paper 4·5 per cent. On the other hand, a broken surface of a substance having the properties of splitting up light, such as glass and polished metals, will disperse—reflect—more light than the same material with a smooth surface. This influences not only lighting up, but also

colour values, for a light reflecting surface, although of the same colour scale as the duller one, will appear more vivid or dense as the case may be. These facts should influence choice of materials and methods.

The next step is concerned with colour harmony and colour contrasts. If we arrange the solar spectrum in a circle instead of a straight beam, dividing it into three main sections, it will be found that opposite red is green; opposite yellow, violet; and opposite blue, orange. These are complementary colours or contrasting harmonies. As Robert Hendrie long ago wrote in his invaluable little treatise on *Colour and Effect*: "Any primitive colour balanced by its opposite secondary, or the compound into which it does not enter, will be accepted by the eye with pleasure, as green balanced by red, violet by yellow, or blue by orange." If the chromatic chart is so elaborated as to include a large number of secondary tints, with the tertiaries between them, any contracting harmony can be ascertained such as "will be accepted by the eye with pleasure." Harmony in colour is the result of easy transition, but too violent a contrast over-excites the eye and is generally displeasing. That is why when primaries are used together they should, as was the custom in periods when they were greatly favoured, be separated by masses, or lines, of white or silver, black or gold. Another peculiarity is clearly stated by the author above quoted: "Repetition of colour may sometimes be used to great advantage in order to render negative the same colour when too predominant in the work; should your picture [wall or ceiling], for instance, be too red, yellow, or blue in hue, a repetition of the same colour, but of a more powerful intensity, in drapery or figure of the foreground [dado, skirting board, or cornice] will render the former too predominant colour comparatively neutral." Such treatment may, however, easily become too monotonous, whether it be too exciting or too depressing. In decoration monochrome schemes may often be soothing, sometimes (with pale blues, yellows, greens, or greys) very beautiful, but are rarely distinguished.

The late A. S. Jennings, whose book on *Paint and Colour Mixing* is a most useful guide, drew up the following list of colour harmonies, which, while not pretending to be comprehensive, is very suggestive:

"*Reds.*—Deep red goes well with medium grey and coral red with turquoise, if the red is of a low tone and the ground somewhat yellowish.

"*Blues.*—Blue and orange harmonise, but if the blue is deep, a yellowish pink colour may be preferred, or a yellowish green can be used instead. An indigo is rarely employed in interior decoration, as it is too strong and sombre, but if it is used an olive green harmonises with it. Cadmium yellow may be used with turquoise and a rich gold colour with a bluish grey. Ultramarine may be contrasted with a yellowish green, but it will have to be dark because the ultramarine is somewhat strong.

"*Yellows.*—Yellow and violet go well together, but the strength of each must be carefully proportioned, and it is worthy of remark that if the proper proportions are obtained, the result is very charming decora-

tion. Light amber yellow is a variation of the foregoing when used with heliotrope. The purples harmonise with yellows, and a rich violet suggesting a plum can be used with sage green."

This is a side of the question which could be enormously extended and yet leave much to the taste of the craftsman. It is one also largely dependent upon style. In period decoration, for instance, it may be broadly stated that Gothic and Renaissance decoration, including with us the Tudor period, vivid colouring, mostly the Primaries, is needed; in the William and Mary and Queen Anne period, the Tertiaries are to the fore; with the Georgian age, following the French Louis Quinze and Louis Seize styles, light tints predominate, the Regency style being associated with white and gold, the Adam with soft pinks, blues, greens, and greys. An Oriental scheme suggests bright colours, and many of them with gilding or white as foils. Modern enterprise has given us an extraordinary range of colour and types of paint, but the Primaries are sparingly used, sombre tones avoided, and prominence given to soft colours, with a leaning to light pinks and yellows. The charm of broken, or mottled, colouring, produced in many ways, has also been skilfully developed, often strongly emphasised by contrasts in surface texture.

HANDLING OF COLOUR

Although there are exceptions the general rule is that the ground colour should be weaker in tone than that laid upon it. We have seen the principle explained in the paragraph referring to repetition of colour, where the touches of stronger tone are suggested as a means of softening the dominance of the background. This applies equally forcibly to contrasting polychromes as it does to monochromes. Thus a medium-grey background looks well with mouldings or other ornaments of deep red; orange or yellows on lower-toned blues; violet on yellow; or pink on cream. White will take black and any colour, be the tone clear and bright or soft. The same applies to silver. Gold in its lighter tones, often greenish or pinkish, may be taken as an example; in its richer, darker tones it leans towards the exceptions, as it will take white or pale pink or green ornament. Also among the exceptions is white on black. At one time, not so long ago, black walls and fabrics with fairly heavy white ornament were much in favour, a fashion which has happily abated. But there can be no doubt that the contrast is effective, and that it can often be judiciously introduced in moderation; for instance in friezes. This exceptional treatment is also seen in white ornament, for instance pateræ, medallions, and figures on strong-coloured backgrounds. Another exception is the use of dark, transparent scumble colours on light luminous backgrounds, especially when the texture is rough and high lights can be gently wiped off.

A modification of this rule applies in the placing of one colour above another in the vertical plane. As a rule the strongest, certainly the darkest, colour or shade should be reserved in a room for the skirting, the

dado being a shade lighter, the upper part of the wall yet lighter, and the lightest tone reserved for the ceiling. This arrangement is pleasing to the eye and lends apparent height to a room. When the order is reversed the room is apparently dwarfed and the eye apt to be strained. This lightening of the tone as the eye travels upwards does not prevent the use of stronger colour in reduced masses in such positions as banding or mouldings at the top of the dado, panelling on walls, in friezes, and on the ceiling. Indeed, the ceiling is very commonly an exception, often receiving heavy decoration in raised ornament or strong colour ; but this is rarely tolerable in all but very lofty rooms.

We may see how this works out with some of the more popular colours for walls. A brick-red filling will need a dull blue dado (a slate blue if the body of the wall is a light shade of brick red), the frieze old gold. With a dark Pompeian filling the dado could be deep blue grey, the frieze dark buff. With the lighter reds the woodwork could be raw umber brown with ivory or white mouldings ; with the Pompeian sage or myrtle green with amber mouldings. Peacock-blue filling, dado claret, frieze brownish gold, and for woodwork orange red, deep amber, or a good brown. Olive-green filling, Venetian red dado, golden-brown frieze, woodwork crimson lake with straw or pink tone for mouldings. Grey green filling, Indian red dado, slate blue frieze, woodwork primrose with scarlet mouldings. Amber-yellow filling, Indian-yellow dado, cream frieze. Golden-brown filling, plum-brown dado, apricot frieze, a reddish purple for woodwork with plum or iron-grey mouldings. Lavender-grey filling, rich red dado, silver-grey frieze, either salmon colour or deep blue for woodwork.

MATCHING COLOURS

Matching colours is always a difficult task. While normally a good, bright daylight is the best for the purpose, it is not always so. For rooms which are only seen in artificial light, that particular light should be used, as this will often greatly falsify colours, especially those of textiles, so that a good match and a harmonious blend by daylight may look all wrong by gaslight or electricity. Under such conditions a perfect match of paint and textile in daylight will appear flat or garish when lit up.

As regards paints, it must be remembered that the tint of a matt paint always weakens as it dries ; distempers and water paints in powder darken when mixed with water, but pale on drying, and paste colours also pale. A glossy paint or enamel shows no change. Therefore attempting to match by comparison of the pigments before use is not suitable. They must be thinned and toned for the job, and then brushed out on a smooth board or a sheet of glass. It will then generally be found that the matt paint requires more stainer, and trials can be made until the right, brushed out and dried, match is attained. If exact note is made as regards quantities there will be no trouble in mixing up large batches for the job. If a ready-mixed paint has to be toned down with white and livened with more staining pigment to match an already painted surface, or some

other material, it is advisable to proceed by sample, that is, small quantities, brushing out and allowing to dry, noting quantities and then making up bulk. This will in the end save time and trouble. Adding varnish to paints, or varnishing the painted work, will also modify tint and shade values, usually heightening them, but not always, according to the nature of the varnish.

Another form of matching is one by which we try to harmonise colour schemes by selecting the ground colour, or some other dominant colour in a wall-paper or in upholstery. Here the problem of matching is complicated by securing harmony, which will determine whether the ground or some part of the ornament, and if so, which part, must be selected for matching. The wall-paper or other material should be hung up in a good light, and in the matching if there is any doubt two or more matchings should be made. Then the paint, or paints, should be brushed out on a fairly large scale, and when dry brought into contact with the material. It will then be able to be seen whether the match is a good one, and is satisfactory from the harmonising point of view. It is far easier if the hangings or upholstery have to be chosen to match or harmonise with the paint, but too often the painter finds that this order is reversed. This is particularly the case with large public buildings, and also in cases of redecoration, which may have to serve as backgrounds for precious hangings or furniture. One of the ways out of such difficulties as these is to adopt neutral colours, or a dull red, or old gold, which is also the solution when valuable collections of pictures have to be displayed.

VARIATIONS IN APPLYING PAINT

Many variations can be obtained by means of the way paint is applied, and also by the selection of paints of different textures. We may have glossy, semi-matt, or matt surfaces ; surfaces which are smooth, others of many degrees of roughness. The standard method of obtaining a high gloss is by means of three- to ten-coat work in a carefully prepared surface with a finish of two or more coats of pale copal varnish. This procedure, however, is rarely adopted now. In place of that varnish is added to the paint in the paint shop, or more often still, ready-made enamels are applied. The value of glossy paint is that it brightens the colour, increases illumination by reflecting light, and has a hard surface which does not harbour dust, is easily cleaned, and wears well. On the other hand, over large surfaces it is often considered too hard and glaring. A useful compromise is to have a matt paint for the walls and enamel for the woodwork, skirting, dado, and moulding. This gives a pleasing contrast and extra protection to parts receiving most wear and requiring more constant cleaning. Obtaining gloss by varnishing over flat paints has certain advantages, as it permits of some variations in effects. A varnish may be used to brighten or darken colour, and may itself be tinted, while with certain high light-dispersing types we can obtain the lustre effects of precious stones, producing a shimmering play of two or

more colours or shades. Another good point with varnishing is that renovation can generally be carried out by rubbing down and revarnishing, without disturbing the expensive three-coat paintwork beneath. Then, again, flat and glossy can easily be combined by partial application of the varnish.

High-class enamels drying with a hard gloss can be advantageously used on outside work, as, not being so easily attacked by impurities in the air, they give added protection to the woodwork, and maintain a fresh appearance for a long time. Where extra-high finish is required, for instance on a door, two coats of enamel should be given, the first one being rubbed down by soaking a piece of felt in water and dipping in finely ground pumice-stone.

As regard smuts on outdoor painted surfaces, from tests carried out by Dr. H. A. Gardner it appears that for exterior linseed-oil paints the dust and smut collection is usually in proportion to the oil reduction. Among other determining factors are the following: (1) the deposition upon a paint surface of moisture containing soot particles may result in a quick change of the carbon to the oil in the surface of the paint, the particles of carbon tending to go into the interface oil-water and becoming strongly bound to the surface; (2) paints which chalk rapidly tend to maintain clean surfaces, the chalking pigment gradually being removed with any deposits of carbon to present continuously clean surfaces.

Dr. Gardner suggested it would therefore appear, as a result of these investigations, that where exterior paints are used around industrial communities (wherever, in fact, smoke contaminates the atmosphere), such paints should be applied with a maximum concentration of pigment. Where paints are thinned by the painter, the minimum possible quantity of oil that is required to make the paint brushable should be used with the necessary quantities of turpentine or other thinners. Paints of this character usually fail by gradual chalking, and do present high-gloss surfaces which would attract soot. Moreover, such paints are usually very much more durable than paints to which large quantities of oil have been added by the painter. This has proved true where exposure tests have been made under varying climatic conditions. Exterior paints which contain a high percentage of bodied oil of the type that does not dry rapidly may attract dust particles, but a reasonably small percentage of bodied oil is not objectionable, and may be quite desirable in producing a film that is smooth and free from ridges and brush marks, which are sometimes observed with raw-linseed-oil paints. Ridges and brush marks naturally include little hollows or valleys in which deposits of carbon may find lodgment and become difficult to remove by rain washing. It is probable, he held, that the most satisfactory method of preventing darkening will consist in adding to each gallon of white paint from ½ to 1 pint of four-hour (half-time) white enamel. Quick initial drying will result and excellent durability be obtained. This recommendation is for final-coat work.

From the last three sentences it will be seen that the opinion that high-class enamel provides a clean and lasting protection for outside work is fully confirmed.

A matt finish generally softens light colours, though it is apt to deepen dark ones, while it lessens glare, and is, therefore, greatly favoured for domestic interiors and picture galleries. A matt finish can be obtained by rubbing down oil paints, using distempers and water paints, washable flat wall paints (distempers with a basis of lithopone bound in Chinese wood oil), or flat enamels (" flatting "), which contain gum varnishes to give body but tempered with borax, which ensures a dead-flat finish on drying. The last named is perhaps the least softening in appearance, but the most durable. Flat wall paints look well and are easy to apply.

Semi-matt paints and enamels produce medium effects. Among the more useful of these are those with the so-called egg-shell gloss. They have a very faint gloss and a slightly pitted surface. Such paints have a white lead basis, and contain copal varnish, size, and boiled linseed oil. An egg-shell gloss finish can also be obtained by getting up three-coat work in the usual way, allowing it to dry hard, and then rubbing down with soft felt dipped in raw linseed oil and either emery powder or powdered rottenstone. This should be rubbed on evenly with a circular motion, firmly but lightly, taking care to go over the whole surface equally, and corners, quirks, and mouldings with a brush. When completed the work is wiped down with a clean soft rag, and finally gone over with a rag dipped in benzoin. The surface should be even but not quite smooth, having something of the look and feel of good blotting-paper.

The pleasing effects produced by contrasts of textured surfaces have already been discussed, but in practice such contrasts can be carried much farther than by simply placing them side by side, or by merely altering the finish on moulding. Applied ornament, whether flat or raised, can differ from the finish of the ground. We can have high-gloss decoration on a matt ground or matt decoration on a glossy surface, this being carried out by freehand painting or by stencilling. Raised ornament can be produced either by moulded composition, glued on, or by means of plastic paint. This can be introduced in set medallions, over doors and lunettes, in friezes and banding, or in powdered decoration, the last chiefly by stencilling.

Stencilling is a very useful method of decorating. It can be varied from the stiffest conventional style to free naturalistic treatment. The stencils are easily cut and easily applied, both on smooth and rough surfaces—on wood, plaster, paper, or textile fabric—using oil paints, enamels, water paints, or stains, as the character of the ground suggests. Stencilling in enamels on water paints stands out very well, having a richer look than is attainable with distemper on distemper or enamel on enamel. Aluminium paint (2 pounds of powder to 1 gallon of bodied linseed oil on a good surface, $1\frac{1}{4}$ pounds of powder to the gallon a porous one) allowed to dry, stencilled in strong enamel colours, and the whole

finished with a coat of pale copal varnish makes an exceedingly handsome job. Where desired the varnish can be slightly tinted to tone down the brilliance; rose pink, emerald green, and primrose yellow are desirable tints, which are shown off well by the dulled metallic gold. This treatment is equivalent to glazing, and helps to blend the stencilled design with the background.

In plastic paints we have another very flexible means for varying textures and planes. There are two types and several descriptions on the market. Most of them are oil and varnish paints containing plasticisers, and are slow drying; others, however, are sent out in the form of powders, and are simply mixed with water. All of them are applied as thin or thick pastes, thickly brushed on or plastered on with palette knives. In a way they are substitutes for fine-coloured stucco, or more nearly gesso, which they have practically superseded, the technique of their use being much less elaborate. They can be applied with an absolutely level but not quite smooth surface or left with the texture of roughly trowelled plaster. In spite of ease in handling, there is a distinct knack in applying these paints so as to obtain the picturesque waviness and swirls, which, though uneven, must have a certain regularity in repetition of character rather than actual figure, so natural to the material. Apart from this unevenness of surface, by dexterous use of brush and palette knife any description of design can be built up, either in the ground colour or some other combination of colours. Unless a frieze or a definitely shaped pictorial panel is being executed, the most pleasing results are attained when the decoration is in medium relief, rising from and merging into the background. Thus, we may have a ship tossing on waves, gulls sailing against the moving clouds; or rolling downs, with a ghostly tree or two under a streaky sky; ethereal figures flitting in misty atmosphere; all seen vaguely like a pattern on old tapestry or silken brocade. When this is carried out in monochrome you have a picture definite enough, yet in no way obtrusive, the design fading into the wall. If contrasting colours the designs must be more confined within limits, such as a panel over a chimney-piece, lunettes or snags and garlands framing doorways and windows. Any painter who has used his brush in design work can succeed with plastic paint, though it is also a medium which well-known artists employ.

Scumbling and glazing are largely applied to surfaces covered with plastic paint. Properly speaking a scumble is a more or less thick and opaque wash, but with little body, which may be oil or water bound. A glaze, on the other hand, is a thin wash of transparent colour, made up with oil. There are also transparent, heavier-bodied glazes. The two substances are used somewhat differently. Scumbles are washed over finished surfaces, if of a rough texture so much the better, and are then partly wiped off. We thus obtain a blend of colours, the top veiling one being shaded off in depth of tone. It will at once be seen how effective this can be on a rough plastic paint or on raised ornament, for when the

scumble is lightly wiped off it appears as a thin coating on the lower parts of the raised surface, and is thickest in the depressions or valleys. For instance, if we apply sienna or umber scumbles over raised ornament with an ivory finish, when the sponge or soft cloth is applied the top colour is wiped off the edges in varying degree, producing an antique appearance. Other pleasing contrasts result with other combinations of grounds and scumbles. Varnish is often applied over them. Transparent glazes are generally used much in the same way as tinted transparent varnishes, but for certain purposes are more effective, and are far easier to apply, presenting little risk of troubles. A glaze gives a very brilliant finish because the colour beneath it acts as a foil, and the film of glaze itself breaks up and scatters rays of light falling on it. This endows a glaze with another property, that of not only intensifying the colour which it covers, but also altering it. That is the case when a glaze of a different colour is applied to the painted surface. Such blendings must, however, be carefully considered or disappointing jumbles may result. But done judiciously the method is invaluable. Thus, if you give two coats of slate or other grey over a priming coat, and finish with a green glaze, you obtain a deep brilliant green of better quality than you could with three solid coats of green, and at less cost. Carmine, crimson lake, and madder glazes over Indian, Venetian, and Tuscan reds produce a wonderful range of rich colours, full of sparkle and life. A Chinese blue glaze over greens gives a rich series of tender blues. The finest peacock hues are obtained by glazing with Prussian blue and lemon chrome over grounds of Brunswick green and chrome. But successful glazing is only possible on good grounds, which must not have a glossy surface. If the surface is too smooth and hard it had better be stippled with a block stippler. This is not necessary with a softer paint with orange-peel finish. Transparent glazes of this kind can be applied to plastic paints with pronounced texture finish quite as successfully, though with very different effects, as scumbles. It is probably not necessary to labour the point farther, enough having been said to show the many advantages of both scumbling and glazing. It is only to be wondered at that the latter is not more often resorted to in domestic work as well as in the decoration of public buildings.

Still other methods of blending colours require attention. By stippling over a freshly painted surface with a stiff brush dipped in a differently coloured paint, mottled effects of the orange-skin variety can be obtained. The blend depends upon the closeness of the stippling. Another way of doing this, often adopted with washable distempers, is to apply two coats of different colours, or of markedly different shades of the same colour, and while the top one is still fresh to go over it with a stippler. This, of course, gives a broken, pitted surface, as well as a broken coat of colour, mottled in appearance at close quarters, but blending together when viewed from a distance. This blending, as well as a smooth surface, can be obtained by glazing or varnishing. By using a grainer's

steel comb instead of a stippler on a ground of two different coats, the variations are obtained by regular or irregular striations, with lines close together or far apart as desired. By the angle at which the comb is held while drawing it across, the character of the lines can be altered.

By dipping a sponge in paint and dabbing it on a differently coloured coat while still tacky all kinds of mottled effects result, depending upon the pressure used, sweeping movements, and the coarseness or fineness of the sponge. If two, three, or more sponges of different texture are used for two, three, or more colours on a suitable ground, very beautiful, soft cloud effects are produced. Judgment must be exercised as to the depth of colour and the degree of drying to be allowed at each application to procure the amount and kind of blending aimed at ; for we may not only have two or more distinct colours, but endless shades melting into each other, vague at the edges, deep in the centres. By dragging as well as dabbing, the striated " mare's tail " and " mackerel " skies are produced. The same results, with even more delicate blending, can be obtained by paint spraying, though the quick change from one colour to another involves some trouble. The style is equally suitable for walls and ceilings. Carefully restrained use of two or three colours on walls makes an admirable background for pictures, tapestries, and rich hangings.

In certain circumstances, in cottages, churches, and public halls, also schools, it is desired to show the character of the woodwork. Then, if it is not oak or teak, the question arises whether varnishing or staining is the better finish. Much will depend upon the style of the building, its use, its fittings and furnishings, and the woodwork itself. In a good class of the cottage or bungalow type of dwelling or a village hall staining is generally the most suitable finish. The stain can have a preservative basis as well as a pleasing, not too blatant colour, and if properly applied will show up the grain and figure of the wood in its full beauty, while it can be made to harmonise with the furnishings. This does not altogether preclude slight touches of more vivid colour decoration. For instance, the soffits and sides of ceiling beams can, after the protective stain has been applied, be stencilled in oil colour, enamel, or water paint. Similar stencilling or painting can be carried out on a boarded ceiling. This would only be found difficult if the stain was of the creosote order, as that remains oily even after it has well soaked in. Oak and teak will not stain well. If any dressing is required a wax polish is the most suitable. In a church, school, or larger type of public hall, varnishing is better than staining, as it gives some surface protection and is easily cleaned. Here, as with stained wood, slight colour decoration, in any type of paint, can be carried out on the sized wood before varnishing. Stained wood is sometimes varnished. Only oil varnishes are suitable for this purpose. A spirit varnish would bleach the stain and probably itself be damaged in the process. A spirit varnish may, however, follow a spirit stain. The objection to spirit stains is that they are apt to roughen the surface

of the wood, a condition bad for the varnish, even when two or three coats are applied.

Finally, we come to graining. With the colours now available very fine imitations of most woods can be carried out by an expert grainer. These are often wonderfully accurate in every detail and very beautiful examples of colour blending, but they scarcely seem worth the trouble. If wood grain and figuring is desired, then staining or varnishing of the plain wood is the proper course. If the wood is too poor for these treatments, then painting in the ordinary way is the better plan, and will be in closer consonance with modern principles of high-class decoration. Where graining is insisted upon for cheaper work, roller and transfer graining will meet the case and be less expensive than hand graining.

MURAL PAINTING

A great deal of the foregoing remarks applies to mural painting. What is commonly meant by the term is pictorial and other artistic decoration. This, up to the mid-Jacobean period, was extensively used in England; after that being almost entirely confined to ceilings, outsides of churches and the more important public buildings. For some time past now there has been a marked revival in this, being largely applied to cinemas and other places of public resort and to a lesser extent in private houses. Such work is mostly carried out by professional artists, though an increasing number of trained decorators are now taking it up. In any case it is necessary to study the matter, if only owing to the steps that have to be taken in preparing surfaces, and then adding plain decoration to frame, as it were, the finer painting. Then, again, it is to be observed that improvements in the smaller portable types of compressed-air paint-spraying machines are inducing more and more decorators to take up this kind of work, at all events in a modest way.

The preparation of surface varies according to the method of painting to be adopted. Fresco painting is carried out with pigments which are not attacked by lime, mixed in water, and applied to wet, fresh-laid stucco. The foundation must be good, solid, not too dry, with a good key, and on this the setting coat is laid, levelled but not excessively trowelled. The setting should consist of 2 parts by volume of fine sand to 1 part of well-run lime. Fine stucco, made of 1 part of lime putty, 1 part of powdered white marble, and 1 part of silver sand, has great luminosity, and dries exceptionally hard. With fresco the great point is that the plaster painted upon must be freshly made, freshly applied, smoothed but not overworked with the trowel, and painted upon with very fluid colours while the plaster is still wet. The paint must sink into the plaster, which presents many troubles to the painter-decorator, as the true values of the colours are in many cases somewhat obscured, being lowered or deepened in their wet condition. For this reason some painters have used milk, others size; but size will be bound to prevent thorough sinking in, and lead to scaling off in time. Monsieur P. Baudouin, who has done so much for

the revival of fresco painting in France since 1912, insists on the colours being mixed with water alone and applied in a very fluid state. The fineness and freshness of the plaster is the great point. Only so much of the setting must be applied as can be painted on in a day; and the next expanse laid must be freshly gauged. It will not do to knock up left-over plaster, however fresh it may appear. A little of the painted-on plaster must be carefully cut away (not very difficult, as it will be still soft) and the edge wetted before the new setting coat is applied. Colours have to be applied with a full brush, and there must be no attempt at retouching when the colours are dry. If the plaster is good, well laid, and not too heavy colours used, a fresco presents a brilliant, luminous appearance, gaining in depth as viewed from a distance. It should be remembered that fresco painting is still an everyday affair for craftsmen in Italy and the South of France.

Tempera differs from fresco painting inasmuch as it is applied to dry plaster or boards. The surface may be smooth or left moderately rough. The setting coat should be made up of 1 part lime putty to 2 or $2\frac{1}{2}$ parts of sand, which need not be very fine. It should be given a reasonable time to dry, and also for most of the moisture in the under coats to work through. Wood should be sized, stopped, and receive a thin coat of white water paint, slightly loaded with clay or chalk. The pigments, proof against injury by lime, are mixed with chalk or clay and diluted with size. Contrary to the fluid paints used in fresco, tempera is applied in the form of a thin paste, and the *impasto* method, building up in low relief, is often adopted. Tempera should dry hard, and will be to a large extent free from chemical change and mechanical disintegration. It is harder and duller than fresco.

For gesso the proper ground is fine stucco, smooth, but not with a too-polished surface. On wood, after sizing, a very thin film of thoroughly slaked lime tempered with size.

In wax painting, or spirit fresco, the plaster ground should be finished with fine setting stuff, allowed to dry, and then dressed with beeswax dissolved in a volatile oil. This same medium is used for mixing with the paints, so that they partly sink into the priming coat. This is somewhat akin to oil painting.

Professor Laurie, of the Royal Academy and the Heriot-Watt College, Edinburgh, writing in connection with Mr. Roger Bland's cobalt-blue lime and wash work on a cream ground, on the walls of the main tea-rooms at Kenwood, and of Mr. Rex Whistler's vivid polychrome work in the tea-room at the Tate Gallery, pointed out that the best plaster wall for oil painting is one with a finishing coat of plaster of Paris and sand (1 part plaster of Paris to 2 parts sand); but a finishing coat of setting stuff is also good. The plaster, and its under coats, must be allowed time to dry out, and then receive a priming of zinc white ground in oil, or beeswax dissolved in oil. The pigments should be mixed with the beeswax-oil medium thinned with turpentine. There are special paints

prepared thus ; but ordinary oil colours, as supplied in tubes by artists' colourmen, will do quite as well. The colour must be laid on thinly as in fresco, with no attempt of the *impasto* method of tempera or gesso. When dry the painting should receive a coating of beeswax dissolved in turpentine. This must be applied quite thinly, and after two or three weeks, when quite dry, should be polished with a soft cloth. "The result," says Professor Laurie, "will be a slight egg-shell gloss, which will gradually diminish with time, and the thin covering with beeswax, after it has been polished, is the best known protective medium against chemical attack from the acids in the air and, at the same time, enables the painting to be easily cleaned at any future time. The thin, well-polished coating of beeswax does not allow dirt, but excessive beeswax will do it. I prefer pure beeswax for this purpose, but others like to add a little paraffin wax and others a little oil." It should be observed that the drying of the plaster is essential. A sub-Committee appointed by the Royal Academy of Arts to study pigments and mediums reported that moisture gathering under a film of oil paint, by expanding and contracting, will cause the film to crack. This will even occur on canvas dressed as usual with a coat of white pigment ground in oil. On a plastered wall, the priming of zinc oxide ground in oil may not be sufficient to arrest the action of moisture coming to the surface of the plaster.

Other points brought out by this sub-Committee are the following. It was discovered that dried linseed oil has the unexpected property of slowly increasing the refractive index, causing the paints to become more translucent, and at the same time tending to deepen the tone. In order to put this discovery to practical use pigments were examined under the microscope when steeped in liquids having different refractive indices, and from the results the table No. 1 has been drawn up.

TABLE I

PIGMENTS LEAST AFFECTED BY CHANGES IN LINSEED OIL

(*Read from top to bottom*)

Red.	Yellow.	Green.	Blue.
Venetian.	Cadmium.	Oxide of	Cerulean.
Indian.	Light French.	Chromium.	Ultramarine.
Cadmium Scarlet.	Ochre.		
Vermilion.	Chrome Yellow.	Cobalt Green.	Cobalt.
Burnt Sienna.	Raw Sienna.	Viridian.	Prussian.
Madder Lake.	Cobalt Yellow.		
Alizarine Lake.			

A careful reading of this table will show that for solid, direct painting the painter in oils should confine himself to such pigments as Venetian red and Indian red, cadmium scarlet, cadmium yellow, the opaque ochres, oxide of chromium, cobalt green, cerulean blue, and ultramarine. While

for scumbling, glazing, and tinting of white, we should use the siennas, ultramarine, Prussian blue, and cobalt. Flake white (refined white lead) and zinc white are particularly apt to become transparent, and if the under coats are dark, the whole composition will be lower in tone with ageing. To lessen this result, white lead and zinc white should be ground as stiffly as possible, so as to use the minimum quantity of oil. Most oils, but more particularly linseed oil, become brownish yellow with age, and if present in excess in paints, tend to lower the tone (darken). Transparent pigments show this failing more than opaque pigments, except in the case of white lead, which darkens more, and more quickly, than zinc white. As oil, like water, dries by evaporation, expansion and contraction follow during drying, and this may cause cracking, especially if a second coat is applied to an only partially dried under coat. There will be no danger of this if the under coat is quite dry, or, as in some processes of colour blending, the upper coat is worked into the under one. The drying stages of paint are therefore important points, and appear to depend upon its oil-absorbing tendencies. Pigments classified according to this test are shown in order in Table II.

TABLE II

OIL-ABSORPTIVE PROPERTIES OF PIGMENTS

Low Absorption of Oil.

White Lead.
Vermilion.
Indian Red.
Zinc White.
Ultramarine (artificial).
Viridian.
Chrome Yellow.
Yellow Ochre.
Cadmium Yellow.
Aureolin.
Prussian Blue.
Terre Verte.
Burnt Umber.
Brown Madder.
Vandyke Brown.
Raw Umber.
Ivory Black.
Cobalt Blue.
Madder Lake.
Burnt Sienna.
Raw Sienna.

High Absorption of Oil.

This places, as confirmed by practice, white lead in the forefront as a safe priming or ground colour, and the siennas at the lower point. If a pigment requiring much oil has to be used as a first coat, again as shown by experience, danger of cracking is minimised by the partial replacing of the oil with copal-oil varnish, but free from driers. If high oil-absorbing paints have to be used as finishing coats, part of the oil should be replaced by a soft resin varnish. Finally, the Committee recommended as a varnish for fine decorative painting pure beeswax in pure spirits of turpentine, which when dry and polished will resist even the oxidised products of sulphur found in coal smoke.

Water-glass painting requires a well-prepared plaster ground, smooth, hard, clean, and well dried. The priming coat should be of white, or very light-toned, water-glass paint, applied with a broad brush and smoothed out. If the priming sinks in, leaving dry patches, these should be brushed over with more paint. This priming dries quickly, and the decorative treatment should follow on the priming without delay. The powder pigments are mixed dry with equal volumes of finely ground gypsum and chalk, and 2 per cent. of zinc white. The zinc oxide renders the silicate paints insoluble in water, so doing away with any need of a fixing wash The dry pigments are ground into a paste by adding slowly silicate of potash prepared by dissolving one-third of commercial water-glass in two-thirds of pure water (boiled and allowed to cool). The pastes are diluted with more water-glass (stirring thoroughly) to produce a rather thick liquid. Although many pigments can be used, those attacked by alkalis should be discarded. The safest pigments are: black—ivory black, lampblack, graphite. Brown—ochre, umber, asphaltum. Red—Venetian red, red ochre, vermilion, alizarine, brown oxide of iron. Blue—cobalt, ultramarine. Green—chromic oxide, Veronese green. Yellow—cadmium. Naples yellow, yellow ochre, raw sienna. Various greys are formed by mixing white with: (1) lampblack; (2) lampblack and ultramarine, (3) lampblack, ultramarine, and a little vermilion. Violet by adding cobalt and alizarine to white. Mauve by tinting the white paste with Venetian red and ultramarine. Orange by the addition of one of the reds and yellow. Chocolate brown by a mixture of brown umber with Venetian red. Red by tinting white with vermilion; carnation by tinting white with alizarine and a very little ultramarine. Glazing is possible, and very fine colours can be obtained by glazing over tinted priming coats

Something must be said as regards style. Broadly, there are three styles the "classic" or "period," which explains itself, being based on tradition; the "modern," and the "atmospheric." "Modern" is generally characterised by clean washes, without shading, and compositions based on cubes and circles. The "atmospheric" aims at soft, vaporous effects applied both in painting scenery and interiors. It is that most favoured for places of public resort. Much of this work is done with paint-spraying apparatus the method lending itself admirably to the style.

PLASTER MODELLING

Plaster modelling is a craft not greatly in demand, as it is so largely, and more conveniently, replaced by fibrous plaster. Both have their uses in decoration. Boldly modelled plaster is indispensable in a great deal of period decoration—in Tudor and Jacobean ; with strapwork, ceiling pendants, portrait and figure medallions, much of it is painted and gilded. Early Renaissance plaster work is also heavy both on walls and ceiling, chiefly in cornices and over doors, the high-relief work including architectural features, such as deep and complicated mouldings, pediments and consoles, flowers and foliage, and figures. Later Georgian styles, with the Adam period, also need modelled plaster work, often enriched with moulded plaster or composition decoration, but generally in low relief and covered with paint, as with Tudor work, of soft tints and low tones, unlike the richer older colouring. In the mid period of the Renaissance the plaster is often left white. Much of plaster decoration in high relief is moulded and not modelled, stucco casts being taken from plaster or gelatine moulds ; the latter are preferable where the relief is high, the design complicated, with undercutting. In most cases what is required in this way is easily procurable from manufacturers of fibrous plaster, and as already explained, there is no great difficulty in applying and fixing the material. It can be sized, all over or in part, for painting and gilding. Fibrous plaster requires greater protection against damp than solid plaster, as the canvas backing, and sometimes the core, are apt to attract moisture, which then soaks in the less consolidated material.

PAPERHANGING

Although painted walls and ceilings are greatly favoured in all classes of buildings, and many other methods of wall treatment enter into competition, yet the demand for wall-paper and fabric hangings is enormous. The variety of materials of this kind offered the decorator is almost bewildering and often exceedingly beautiful in texture and design.

A wall or ceiling to be hung with paper should have its plaster surface sound, clean, level, and smooth. Any inequalities or faults should be levelled up. A hard, polished plaster does not make a good surface. The plaster should be dry ; if it is damp, moisture, probably together with lime salts, will come through and either detach the paper from the walls or bleach and stain it. If danger is to be feared from free lime in a too-fresh plaster, it should be neutralised with a wash such as is used before painting new plaster or cement rendering. A wall made damp by external causes should receive attention for radical cure, but the local remedy is the pasting on of tarred paper over the damp places, with a fair margin beyond. The tarred face should be pasted against the wall. If the reverse is done the untreated back will soak up moisture which will work through to the front, and then the tarred or pitched material would stain the paper pasted over it. If the case is a bad one, or the wall-paper is very delicate in texture or colouring, lead foil is to be preferred to the

tarred paper. Paper sometimes will not adhere to a wall. This may be due to a hard finishing coat, such as Keene's, or more probably because the plaster has received a coat of silica damp-resisting preparation. In such cases a very thin coat of tenacious quick-setting paste will usually provide the necessary key. On old work attention to the plaster is very much needed. If there is old paper, it should be stripped off. This is done by soaking the paper with hot water, which will soften it, when it can easily be scraped off. Then wash off the old paste with warm water. If the paper is a varnished one, especially one that has been properly varnished after it was hung, it will be necessary to soften the varnish. This is done by applying a caustic or alkaline wash, or better a paste of lime tempered with a caustic remover. The remover must be allowed to soak in, so that the paper is really soft. If this is not done the paper will be difficult to strip and the plaster will absorb some of the caustic, which will have to be washed out. It is well to apply a wash of vinegar and water to any woodwork, such as skirtings, and keep it wet, as a precaution against the caustic. If old plaster is stained, especially ceilings with greasy soot stains, clean off as much as possible and cover stains with patent knotting, followed in bad cases with a coat of white water paint. New and old plaster will require a coat of size before the paper is pasted on ; this is not needed over water paint. Boarded walls and ceilings after cleaning should have one or two good coats of size ; knots and sappy patches covered with patent knotting ; all cracks and joints stopped. Joints should also have strips of thin paper or muslin pasted over them. In such cases lining paper is advisable. This is pasted on as a ground. Lining paper, white under white or very light-coloured papers, brown under others, usually forms a base for all choice papers.

Painted walls should receive a strong wash of soda and water, which must be allowed to dry on. Then wash off, and apply a coat of weak size in which some whiting has been dissolved, to provide a key.

The best paperhanger's paste is made with 100 parts of wheat flour made into a paste with 3 parts of a saturated solution of alum, and 5 parts of saturated solution of dextrine. It must be worked quite smooth into a thick cream. Then a little *boiling* water is mixed in thoroughly, followed by more *boiling* water, until the paste swells and changes colour. Then a few drops of oil of cloves or of formaldehyde (formalin) can be added. If the wall is damp add to the above a paste made of $\frac{1}{4}$ pound of glue dissolved in a little water, adding $\frac{1}{2}$ a pint of hot water when the glue is soft, together with 2 ounces of Venice turpentine. The paste should be used cold after standing a few hours. It is essential that it should be well cooked, perfectly smooth, and free from lumps.

The first step is to measure the room to determine the quantity of paper required, and also the height from floor to ceiling (or skirting or dado to cornice) to determine the lengths to be cut. The rolls are placed on the pasting table (usually boards nailed together and resting on trestles), gradually unrolled and the selvedges cut carefully and accurately with

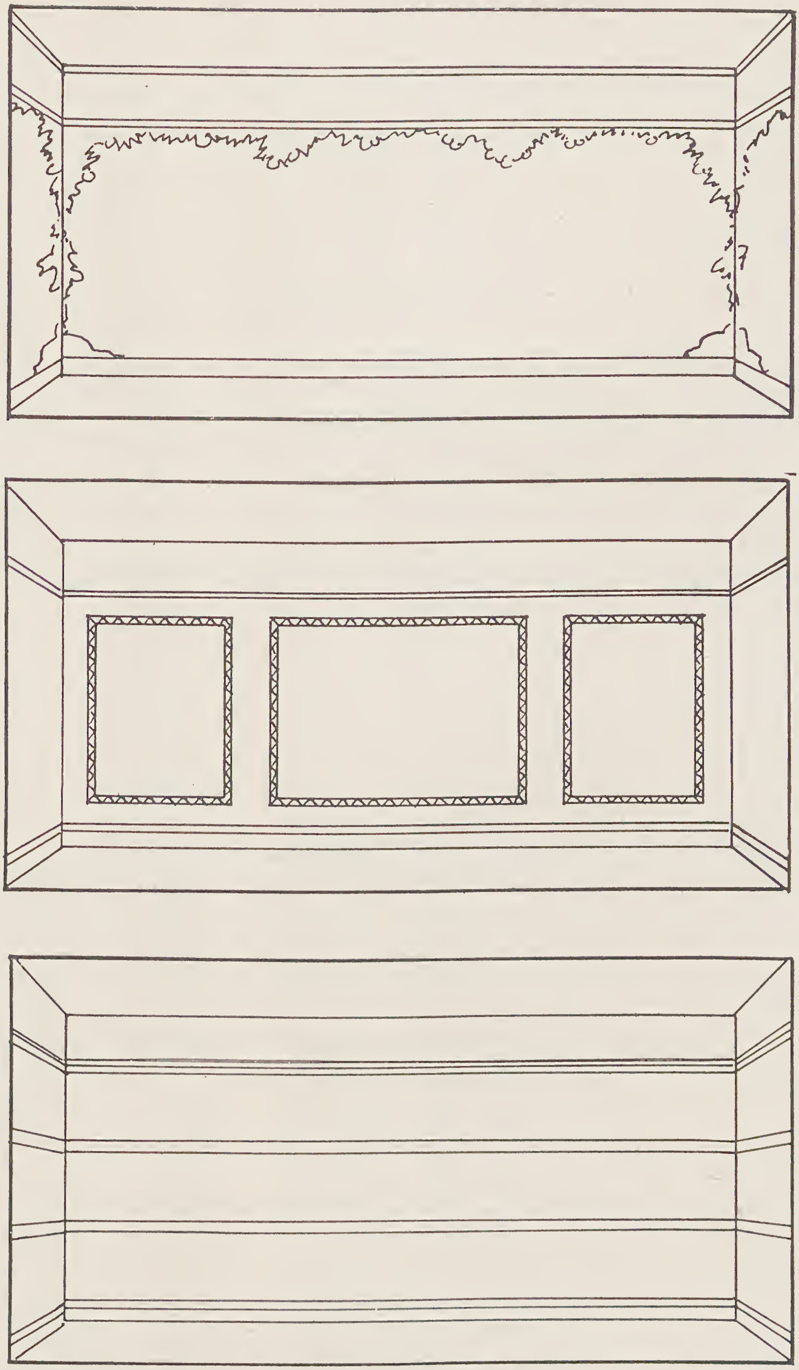


Fig. 111.—*(Top)* Floral border and angles—an informal method of breaking up a wide wall surface. *(Middle)* Panelling—a formal method of breaking up a wall surface. *(Bottom)* The modern tendency is to emphasize horizontal lines.

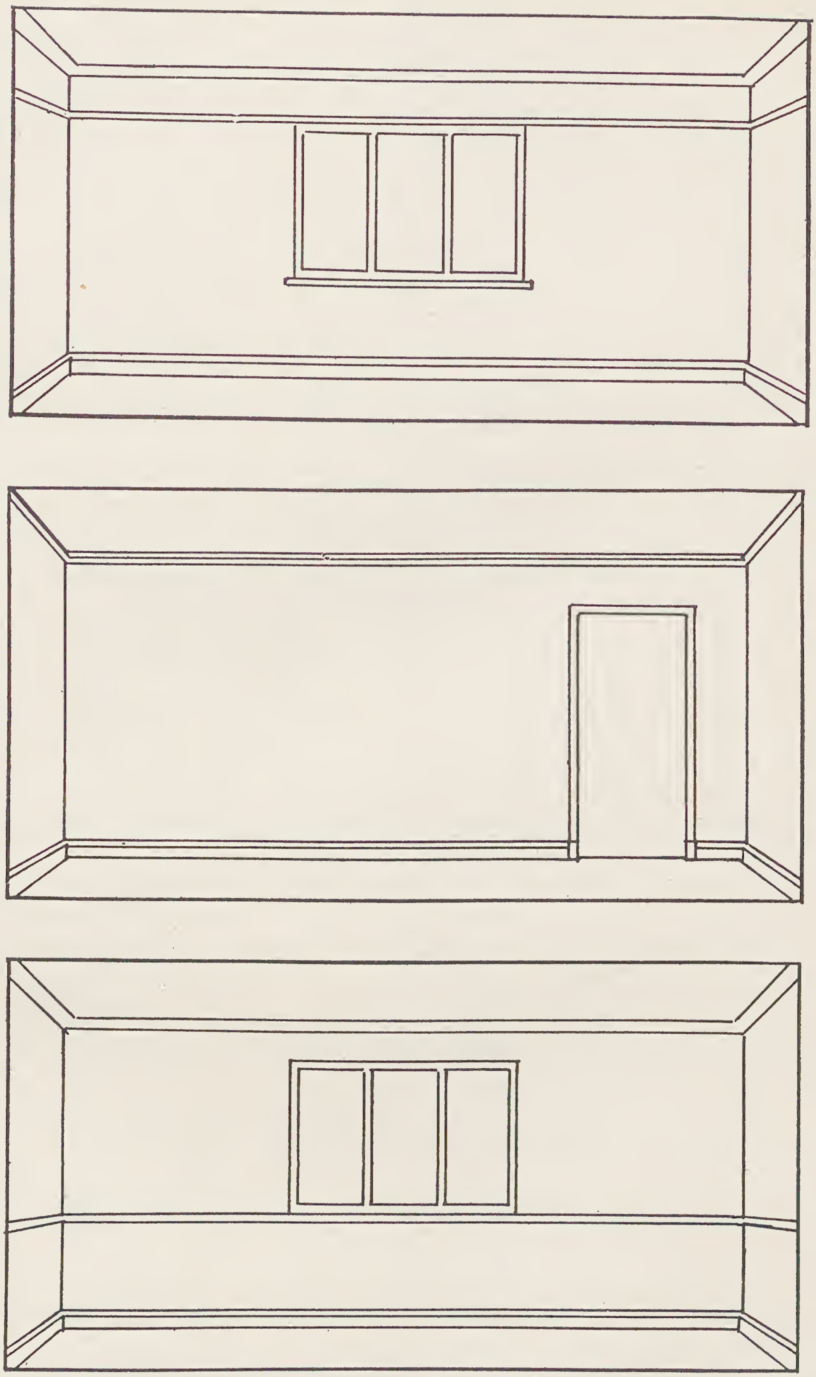


Fig. 112.—*(Top)* Wall treatment with picture rail and plaster cove. *(Middle)* Picture rail omitted or placed close to ceiling. *(Bottom)* Dado band at window-sill level.

a large pair of paperhangers' scissors. Generally one selvedge is cut off as the roll is opened out, and the paper rolled up again ; and when one side is finished the process is reversed. In cheap work one selvedge is left and a lapped joint made when hanging ; this leaves a very perceptible vertical ridge, and in all good work a butt joint is preferred. This is, indeed, necessary with thick, heavy papers. The aim in cutting the lengths should be to secure perfect match in joining patterns without too much waste. Short lengths over doors and windows cause more bother. The actual pasting should be adapted to the paper. Cheap ingrains being porous require stiffish paste and prompt hanging. Other papers require the paste to be applied smoothly, and given time to soak in. Stiff wall-papers, especially varnished or metallic surfaced, are the reverse of absorbent, and they generally require a coat of paste which is allowed to dry on, when another is applied. Two or three lengths are prepared one after the other to allow time for soaking and softening. A section of the length is pasted and then folded over, pasted side to pasted side, and this process is repeated with the other half. In this way a great length can be pasted and is easy to handle when on the ladder. The pasting must be neatly done, so that none reaches the face. The hanging is done from top downwards, and generally either from an angle of the room or from a line drawn vertically from a door. The paper is pressed against the wall with a clean cloth or a roller to ensure close adhesion and the pressing out of all air bubbles. Great neatness is needed in butt joining and in hanging friezes.

Many walls are panelled, specially designed papers and borders being provided for the purpose. Still more decorative are the modern pictorial papers, often with scenery to occupy the whole of one side of a wall, after the style of the eighteenth-century Chinese and Indian hand-painted papers. Other papers are floral, not with all-over repeat designs, but full-sized trailing loops at angles, on the centre of walls, or trees springing from the skirting. These, like the friezes, trailing far down the wall, are cut-outs, the designs being pasted over plain or specially figured paper. Such papers, while requiring extra skill in hanging, add greatly to decorative possibilities, as every room, even when the same materials are used, becomes more individual and distinctive.

Special instructions are issued with Lincrusta Walton. They say: Before unrolling Lincrusta Walton in cold weather stand it in a warm room until the chill is removed. Use the paste hot. First trim the edges by using a sharp leather-cutter's knife and a steel straightedge. An ordinary paperhanger's knife will not answer, as it is not stiff enough. Cut the Lincrusta into the lengths required and paste with the following composition, namely, fresh plaster of Paris 4 pounds, raw linseed oil 1 pint. Rub these together through a fine sieve. Take 1 pound of white glue and add $1\frac{1}{2}$ gallons of water. Boil the glue well and add to the plaster while hot. Stir thoroughly and let the whole stand until cool, stirring from time to time while the cooling proceeds to ensure a thorough mixing with the

glue. If desired, instead of this composition, a mixture consisting of two-thirds of ordinary flour paste and one-third of glue can be used, and this may be applied with an ordinary paperhanger's brush. When the composition or the paste is applied, affix firmly to the wall, putting the edges closely together and rubbing the joints with a stiff short-hair brush. A soft-rubber spherical roller is a good thing to use, as the background can be pressed well home by working between the relief. If any blisters appear, after being pricked with the point of a penknife, use the roller.

Relief pressed materials are often decorated with scumbling colours after hanging. A couple of coats of size are generally needed. When dry, the scumble is applied, and while still wet wiped off from the high-relief parts with a sponge or soft cloth. If desired the work can then receive a coat of varnish. The size used on such material, especially on the stiff highly patterned Lincrusta, should be thin, otherwise adhesion will be bad, the size often partly blocking up the pattern. Then the paint flakes off. This trouble is very apt to occur with distemper, or when one coat of distemper is added to another, say on a ceiling.

When varnished papers are required for kitchens, bathrooms, corridors, lavatories, etc., it is better to buy unvarnished sanitary paper, hang it, give it a coat of good size and two coats of varnish. This makes a satisfactory, lasting job. Ready-varnished papers are difficult to hang, have indifferent adhesion, and do not wear so well. If the latter are used, plenty of time should be allowed for the paste to sink in.

Standard measurements are: English papers 21 inches wide trimmed, and 12 yards to the piece, equal to 63 square feet. American papers, 18 inches wide, 8 yards long, equal to 36 square feet. French papers, 18 inches wide, 9 yards long, equal to $40\frac{1}{2}$ square feet. In measuring a room for quantities required allowances are made for doors, windows, chimney pieces and other parts not papered, but against these deductions an allowance must be made for waste, this depending largely upon the nature of the pattern. Large repeat patterns entail heavy waste, especially in small rooms. Small repeat patterns are easy to match when joining together. Plain, unpatterned papers entail the minimum of waste.

Bilmac Glass-faced Wall Decoration.—This is a successful attempt to combine the simplicity and adaptability of wall-paper with the charm and advantages of plate-glass wall lining. In this case, Bilmac Ltd., a London company, use spun glass as a facing for their wall hanging. The spun glass is very fine, and provides a continuous film possessing the soft, satiny sheen characteristic of this material. It is to be had in bright colours and pale tints, artistically blended, sometimes in bands. The colours are, of course, fast to light, and this form of wall hanging can be freely washed when once up. It presents no difficulty in hanging, being treated like any other high-class, stiffish material, the only precautions necessary being to have an absolutely level surface and perfectly smooth paste, and close-butting joints, as any defects show up with

abnormal distinctness. Bilmac, which is suitable both for private houses and high-class shops, is made 24 inches wide in lengths up to 20 feet.

GLASS IN DECORATION

Glass in its many forms is having a marked attraction for the more creative-minded among architects and decorators, as well as a fascination for the public. It is being used inside our buildings in endless ways, with some examples of outside application. Advance in manufacturing processes has placed at the decorator's disposal a great variety of glass. The silvered form still holds prominence. Mirrors, both small and of quite large dimensions, of rectangular, ovoid, or elliptical shapes, are now often framed flat as part of the permanent panelling, and occasionally as long, rectangular panels on doors and window reveals. If we do not exactly repeat the celebrated seventeenth-century Gallerie des Glaces in the Palace of Versailles, or its poorer imitation at Rosherville Gardens on the Thames near Gravesend, mirrors are used to panel palm gardens, alcoves in lounges, the shafts of columns, and in many other ways that are usual in lending apparent expanse to apartments and also in improving illumination. One often handsome variation of the mirror is seen in placing behind plate-glass panels, sometimes used as large panels but more often as banding strips, glittering coloured foil, smooth or crinkled. This treatment has been repeated in furniture. For instance, in a dining-room where on walls and ceilings a rich wine colour predominated, this colour was suggested in the carpet and repeated in the massive oval table. This had, a few inches from its edge, a broad, shallow, sunken band filled with tinfoil of exactly the same wine tint, and the whole table was covered with a bevelled-edge sheet of glass. In another instance the foil in its sunken recess was placed in the centre of the table. The same treatment has been applied to other pieces of furniture to harmonise with the decorations. Another attractive treatment of mirrors is the bevelling of the plate glass at the back before silvering, in such a way as to give the appearance of breaking up the sheets into a number of large and small panels. It is decorative and most helpful in period decoration of the Stuart and Georgian periods. As regards the use of mirrors in any description of panelling, the decorator must take precautions against damp, which soon damages them. For this reason mirrors should have their edges protected with some waterproof mastic before framing, while the back should be isolated from the wall with waterproofing material.

Apart from mirrors, plate glass is now available in numerous textured surfaces, in a wide range of both clear and opaque colours and the face may be ornamented by means of acid etching or sand-blasting decoration. How extensively such glass can be used in decoration is shown by a scheme for a bathroom published by one of the leading manufacturers of glass. " Wall facing window has pink-tinted plate-glass mirrors above the dado and grey plate-glass mirror to dado height. Above the pink

plate mirror is a band of silvered pinhead morocco (a roughened surface imitating morocco leather on an enlarged scale). The window side of the room has sliding screens to a terrace beyond, glazed in the upper panels with kaleidoscopic glass tinted pink, and below in polished clear plate." Much of this plate glass used for panelling is toughened, and how this can be applied on outside work may be seen in the *Daily Express* building in Fleet Street, London. The façade presents a series of horizontal strips of gleaming polished black glass, alternating with long unbroken bands of metal-framed windows. The large plates of toughened glass are fixed in metal frames secured to reinforced concrete walls. The glass is bedded in mastic in the flanged metal and held in position by silver-coloured strips of metal, so that any panel can easily be replaced. Between the glass and the reinforced concrete is a rendering of pumice concrete.

Glass in the form of tiles and mosaic will be referred to later, but mention must be made here of moulded glass already much used in decoration, and destined to be more so, because, even more than toughened plate glass, it can serve in a minor way a structural purpose. This type of glass when in a molten state is run into moulds, so it can be given any desired form as well as surface decoration, thus differing from ordinary plate-glass manufacture which receives surface decoration from engraved plates on the pouring table or from levelling and thickening rollers. Such glass is made into large or small sheets, strips, either flat, or curved, even into domed and bowl shapes, while the decoration can be in very high relief. It is being largely used for panelling, the construction of doors framed in untarnishable white or yellow metal and screens. The panels may be framed in wood, sometimes lavishly inlaid with marquetry, but more usually in slight fillets of bronze, aluminium alloys, or one of the stainless steels. The metal-work is often fanciful in shape, even floral. Doors are used for shutting off the outer lobby from the lounge hall, between sitting-rooms and terraces and conservatories, also occasionally between dining-room and billiard-room. As certain types of the glass are cloudy, tinted, heavily embossed with roughened surface, the panels can obstruct vision while admitting light, thus really serving screening purposes and so making them quite suitable between bedroom and boudoir or dressing-room, bathroom, and so on, but still more for screens in corridors, on staircases and other places, where it may be necessary to obstruct a view though necessary to admit light. In some instances windows are double, plain glazing outside, moulded glass (roughened or tinted) on the inside, and with electric lights between, so that soft illumination is obtained both by day and night. This screening of light is largely adopted with electric lamps sunk in recesses of walls, the embossed moulded glass panels being flush with the surface. Of more general application are the standard and adjustable hinged wing fire-screens, wherein the character of the material and its sculpturesque ornament is admirably shown. Roundels and rectangular plaques of this

material are also being set in open metal-work screens for the comfortable but unsightly radiator. Again, we find them in window screens, either as complete panels or set in scrolled metal-work. In public buildings, such as hotels, restaurants, and shops, such decorative transparent or translucent screens are of service in endless ways. It is to be observed that this moulded glass, whether colourless or coloured, with its peculiar satiny sheen (unlike the hardness of crystal or clear ice), blends perfectly with wood or metal framing of any kind. Colour, moreover, owing to the nature of the glass, is distributed as in a cloud, not being uniform but varying in depth, which again makes it so easy to fit in with walls, furniture, and upholstery.

Glass in large slabs can be fixed in decorative metal framing, sliding into grooves, and fixed into the walls. This method has the advantage of easy removal and replacing in the event of breakage. More generally, and particularly with smaller slabs and tiles, the glass is set in a good lime putty and fine sand mortar, or in mastic, but the fixing should be a close butt joint, except in the case of very small tiles when a very thin plaster jointing is permissible.

TILES AND MOSAIC

In addition to self-coloured, smooth-faced tiles, there are others with polychrome and embossed decoration ; these are either complete in each item or require a number to make up a pattern. The better-class tiles have the colour slightly unevenly distributed under the glaze, which gives them a softer, more pleasing appearance. Such tiles are largely used in finishing fireplaces, but are also suitable for wall lining, or for dadoes and friezes, and some of them are also fit for flooring. The precautions to be taken in setting tiles is to soak them well in clean water and bed them carefully in lime putty mixed with silver sand. The jointing must, as a rule, be very thin, but there must be a cushion between each tile, otherwise there would be buckling of the surface and falling away of the tiles, caused by expansion through changes of temperature. Buckling also arises when the backing of concrete or plaster is not sufficiently matured ; the " green " backing will expand and contract, or worse still exude moisture and lime salts, which may be sufficient to disturb the setting in which the tiles is bedded. Tiling must not be attempted until the concrete or plaster is reasonably matured. Care must be taken that there is a good key for the setting, and that the backing is sufficiently wetted. The weight of the tiles is quite enough to cause dislodgment where adhesion is bad.

Mosaic is decoration, conventional, geometric, floral, or pictorial, formed of tesseræ, small cubes, of coloured glazed clay (miniature tiles of variegated forms), or of glass, or of coloured marbles. They are generally used separately, but are sometimes mixed. The tesseræ are bedded in a matrix of lime putty and sand or mastic ; usually washed over with a thin grout to fill interstices, then wiped off with a damp cloth. Mosaic

decoration may be in the form of large or small panels, on walls or ceilings, dadoes and friezes, or in the treatment of fireplaces. Glass mosaic looks well in the last position, also in narrow coloured bands surrounding tiled floors either in halls or palm gardens. It does admirably for fountains; more particularly for lining the basins. Pictorial panels and deep friezes are mostly reserved for public buildings.

A bold handling of tiles and mosaics may be mentioned by way of suggestive illustration. A church with exposed red brick walls, and red brick piers, with vaulted white stuccoed ceiling, had its severity lightened by a frieze of blue-green glass tiles, edged with dull gold, forming a harmonising bond between the rich mosaic panels over the altars and the tympanum of the west door. This simple, direct way of introducing beautiful detail in a strictly economical treatment of an interior could scarcely be better. It was purely embellishment, yet looked structurally correct.

INLAYS

While the painter's art still rules paramount in the decoration of interiors of the highest class, there are other processes which are meeting with appreciation and consequently deserve attention. Certain architects who pay much attention to the decorative finish of their work appear to be enamoured of metallic sheen and the richly varied tones taken on by metals as they age and develop patina. One of these is fond of silver-lacquered furniture and walls. And this is more commonly seen in silvered banding, friezes, pillar or pilaster capitals. Another has experimented with copper on walls, a notable instance being in a large sitting-room in a house in Westminster. It is not quite even, partly hammered, the metal covering the whole of the surface. It takes on warm tints under simple routine burnishing with soft cloths, the green oxides characteristic of outside sheet-copper work not being allowed to appear. These are extreme instances, but serve to show how far experimenting has gone. Silver or gold friezes, grounds with embossed or coloured enamel ornamentation are more common. Sheathing with metal sheets or foil cannot be replaced by painting with " bronzes " or aluminium powders, but can with certain types of " Plymax."

It is, however, in the many kinds of inlay that one phase of decorative development shows itself. There is a fraternity of Scottish plasterers who have done some remarkable work with tiles and slabs of cement mortar on which elaborate designs are sunk by means of dies or otherwise, and then filled in with appropriately coloured cement or composition. Here is a revival of the old "encaustic" tiles so boldly used in our native architecture from ancient times to our own days.

Wood inlay, both in the form of parquetry and marquetry, still holds a limited place in decoration, even in its pictorial form. But there is a modernistic development of this last, seen at its best in the work of the Rowley Gallery, Church Street, Kensington. There panels for screens

wall decoration, and so on, are built up with elaborate pictures simply by selecting figured woods and then introducing inlays, mostly in large pieces of self-figured and self-coloured woods. Only occasionally do we find silvered or gilded backgrounds ; otherwise the natural figuring and colouring alone go to make up the panels with landscapes, flowers, animals, figures. It is a legitimate form of decoration, producing admirable effects.

The same method has been applied to marbles, perhaps the most outstanding and accessible example being in the Lyons' Corner House in Oxford Street and Tottenham Court Road. In this instance, the artist, having a free hand and vast expanses of wall surfaces, has been able to carry out his scheme in great elaboration and on a lavish scale. It has been suggested that marble lining for walls is too cold in appearance for the English climate. This is not the impression created in this case, partly owing to the interest of the scenery shown, partly to the variety of rich-coloured marbles used. The scenes depicted (so to speak) are panoramas of mountains and lakes, with drooping larches and other typically foliaged trees, and these panoramas have been carried out with differently coloured marbles, selected for their peculiarities of veining and texture, as well as of tinting. It all looks very natural, as though it were scenery viewed from a distance through a slight veil of mist. To the making up of these pictures have gone cipollinos from Switzerland and Greece, jade green from Ireland, Numidian red from Africa, verde antique from Greece and Italy, other kinds of verde antique from the Alps and Tunis, lovely *fleur-de-pêche* from Italy, with other vivid or tender-coloured stones from remote corners of the earth, each chosen for its special fitness to represent a given object or effect. It is a varied and costly " palette," and no doubt such bold and elaborate treatment needs large surfaces, perhaps only suitable for public buildings. But seeing what has been achieved here, and bearing in mind the same type of wood inlay, there would seem to be wider opportunities for the style.

WAINSCOTING

Wainscoting, or wood panelling, either for complete wall lining or merely as a dado, is able to play an invaluable part, both structurally, to use the term in its extended sense, and decoratively. Wainscoting is an elaborate construction of panels mortised and wedged into stiles and rails and the skirting. The walls which are to be masked should be dry and it is well if they are given a rendering of waterproofed cement mortar. In best work the panelling is not fixed immediately against the walls, but to a framework of battens from $1\frac{1}{2}$ inches to $\frac{5}{8}$ inch, nailed to the walls, or plugs or fixing bricks in the horizontal, with vertical strips placed vertically. The distance of these apart will depend upon the character of the panelling, as, of course, screws cannot be driven through large smooth panels. Woods used for wainscoting are oak, chestnut, cedar, pine, and

walnut. Walnut is now the most commonly used, and pine where it is to be painted or stained and varnished.

Style in the designing of wainscoting varied with the period. Prior to the Tudor period panels were small, decorated with linen fold, often arched and traceried, and with an embattled cresting. In Tudor times the panels were larger, often raised, the stiles broad, and in the form of fluted pilasters. In Elizabethan and Jacobean times panels were rectangular, sunk with raised stiles and rails, generally carved. Strapwork adorned panels and stiles. Later Renaissance brought raised, long, rather narrow panels, carefully balanced. Then much larger panels came in, framed into elaborate mouldings and occasionally plain or fluted pilasters. Oak was the principal wood down to the Restoration, with white wood painted for the cheaper work. After that chestnut, walnut, and cedar. Under Charles the Second and even in the Queen Anne period, much of the decorative carving was carried out in limewood or pearwood and " planted " or glued on to the wainscoting. During the Queen Anne and Early Georgian Periods pine wainscoting was very generally used, and this was painted in the colours and styles then prevailing. The method to be adopted with wainscoting of this kind is to coat all knots and sappy places with knotting, stop defects, sandpaper lightly, apply one coat or two of size. The priming should be of white lead thinned with equal quantities of boiled linseed oil and turpentine. In place of a second coat of white lead tinted, a thin coat of good enamel, tinted to a shade lower than the final colour, does well. If it dries with a gloss it should be rubbed down. Follow with a coat made up of one-half the under coat and one-half the final coat. When dry rub down with fine sandpaper. A good coat of enamel, tinted as desired, should be sufficient. The finish should be semi-matt. Mouldings and carvings after priming receive a coat of brighter colour, often finished with a glaze. If this finish should look too bright for the furniture and fittings, an antique appearance is given by a thin glaze of raw umber ground in oil and thinned with turpentine.

In modern wainscoting panels are large, plain, with or without mouldings, and substantial framing. The wood is either wax polished or stained and varnished, so as to show off the beautiful figuring of the American or Australian walnut and other exotic woods. In the Unilever House on the Thames Embankment much of the wainscoting is in highly figured Australian walnut with a darker wood framing. In the India House, Kingsway, more varied treatment can be seen, for there are mixtures of Indian woods with some inlay.

Lighter wainscoting can be bought ready made. In " Detachable Wood Panelling," a substantial type of plywood is used, the rectangular panels sliding into grooves in the traverse mouldings. It can be quickly set up or removed. In the " Interlocking Rail Panelling " of Samuel Elliott & Sons, Reading, the panel units fit into the rails and stiles, the framing being of 1-inch stuff, easily fixed by invisible ground screws

to breeze concrete or plugs in brick or plaster. In "Fenestra" we have a light framework of pressed and appropriately enamelled steel with rolled mouldings, easily fixed to any wall, into which the wood slabs or panels are slipped. Any period style can be copied in these. Then there are the composition panellings of which "Dekart" may be taken as a type. This is not wood, but a prepared material which can be pressed and modelled to reproduce any kind of wood and style. It is remarkably light, is damp- and fire-resisting, will not split or warp, but can be sawn, and will take nails or screws.

PLYWOOD

Plywood interests decorators as a material for lining walls, covering ceilings, floors, and for building up doors or fittings, which can be highly decorative in itself or provide a good base for applied decoration. Plywood is a manufactured material, but with only slightly modified natural wood. Woods of various kinds are sawn into very thin sections, or veneers, which are then re-formed into a solid mass by cementing together under enormous pressure. There are three-ply and multi-ply panels, according to the numbers of veneers. When built up on scientific principles it possesses remarkable qualities, for it is light in weight in relation to its thickness, is wonderfully pliable, strong, and will not warp. This is because each veneer has the grain opposed to the other and thus the strains are equalised. Another point is that normally the outer veneers which take the greatest strains can be of specially tough wood and the core of a cheaper kind. On the other hand, a valuable and perhaps weak wood is used as a very thin top veneer for the sake of its beauty. The woods most commonly used are birch, alder, gaboon, Oregon pine, ash, and oak. Standard three-ply is made into standard thicknesses of $\frac{1}{8}$ inch to $\frac{1}{4}$ inch, and in some woods $\frac{5}{8}$ inch. Multi-ply in thicknesses from $\frac{3}{8}$ inch to $1\frac{1}{2}$ inches. When damped and softened by steam during the process of manufacture it can be shaped in presses almost as easily and freely as steel or aluminium alloy sheets; thus one can have a seamless dome or half-circle coved section in plywood. Moreover, during such processes the material can be embossed with decorative designs, which is important for wainscoting or ceiling covering as well as other purposes. "Cleanness" as applied to plywood refers to its freedom from knots or similar blemishes, but has no bearing on quality as measured in strength or other physical characteristics. "Cleanness" will be important if the plywood is to be merely wax polished, stained, or varnished, but the cheaper kind, because with less perfect veneer, will do quite as well if it is to be painted or otherwise hidden. Another convention of listing should be remembered, the grain always runs in the direction of the first-mentioned dimension. Thus, 60×48-inch plywood has the grain running lengthwise; in 48×60-inch plywood the grain runs across. Of course this refers to the top veneer.

For wall and ceiling lining the thinness of the sheets, the lightness of

weight as compared with bulk, and the width and length of the smooth area available are all so many advantages. Owing to its lightness the wainscoting can be fixed close up to brickwork or concrete, being safely nailed to roof wooden battens fastened to the walls. Plywood ceilings are formed by nailing the sheets to the soffits of the flooring joists. And here it should be observed that if attention is paid to grain the plywood is pliable enough to be bent so as to form coved sides to the frieze. When plastered, or cement rendered, surfaces have to be covered by plywood it can be placed right against the plaster, wooden plugs or fillets being let into the walls to receive the nails. This saves space. When there is to be such close proximity of wall and lining, some waterproof sealing should be adopted either as regards wall or plywood.

One of the advantages of such a compound material, at once thin, reasonably pliable, yet stable, not liable to crack or warp, is that it is possible to obtain extensive unbroken expanses of handsomely coloured and figured woods, sometimes of a kind too brittle for ordinary veneering, or too hard and expensive for use in the solid. In this way, exceedingly beautiful panels are produced, though too often repeated, or on too big a scale, may become tiresome by reason of their monotonous flatness. It is a mistake to attempt to break up this monotony by means of carving, though moulded ornament need not be excluded. Indeed, with the many compos available, including wood pastes, very charming and delightful effects can be secured, introducing ornaments cast from stock or special moulds. Such ornaments can be planted in centres of panels, as wreaths round bracket-lighting fittings, or as friezes. Ordinary borders and mouldings are, as already stated, ready pressed on some types of plywood panels. But ornament of the kind just described, more particularly in borders, mouldings, and friezes, may be gilded, silvered, or coloured, the metals and tints being chosen to blend with, or by contrast bring out the charms of, the tones and figurings of the veneer. With some woods, gilded mouldings with a red beading or fillet (running from scarlet to shell pink, according to circumstances) are indicated, with others the fashionable silver with pale blues, greens or lemon to primrose yellows will be more effective. Even if we do not abandon the characteristic flat smoothness of the material, colour can come to our rescue in several ways, the two most appropriate being stencilling and spraying suitably applied.

For work of this kind the stencils should be fairly simple and rather open, and should be applied as borders, corner pieces, or in a frieze, rarely on the open spaces of the panels. Better effects will be obtained if glossy paints are applied on a matt varnished surface (or on silvery grey woods) and matt paints on surfaces to be brilliantly varnished. By a careful choice of the stencil design it will often be feasible to bring in the natural figuring of the wood as a telling part of the decorative scheme. This utilisation of the background is one of the reasons why simple, open stencils are desirable. On the other hand, on dark plywood a deep

frieze with armorial shields in heraldic tinctures, linked by acanthus leaf scrolling or arabesques, will look quite well ; while on some woods, and for certain rooms, a procession of figures, each standing out distinct, in black or gold, could be tried. With appropriate stencils and pigments, the effect obtained would be of that of the intarsia type of inlay.

Even more varied and fine effects can be secured by the use of paint spraying. When using the air-brush it is possible to treat the plywood as the old masters dealt with an oak or a beech panel, the elaboration of the painting only being limited by the abilities of the artist. This, however, would be to misconceive the qualities of the material to be decorated, for plywood used as a wall or ceiling lining is usually of a choice description. But short of regarding it as an easel canvas, or a stucco surface for grand mural painting, there are many ways in which the air-brush can be used to add interest to the already beautiful panelling. It may be a question of producing an elaborately finished painting in the centre of a panel—a dainty landscape, group of figures, or floral spray—a gaily coloured border or pictorial frieze. Then the artist should proceed as though painting on plaster or on silk, when the paint is applied thickly and a full range of colours will be available. That is one way. Another, which both the method and the material to be decorated suggest, is to produce shadowy effects. While in stencilling and painting it is better to operate on a surface prepared by the application of size, with " shadow " or " atmospheric " painting the spraying should be done on unsized wood. For this type of work the paints must be thin and the tints soft. The spray will have to be very fine, the brush held well away from the surface in order to secure a deposit of colour mist which will not too closely coalesce. The designs should not be too crowded, the colours such as will blend with those of the natural wood. Then it will be possible to obtain a decoration which, while it will break up the sameness of the wood grain and veining, will be almost imperceptible except in certain lights and from certain angles. The degree of shadowiness or prominence will depend upon the body of the paint used, the lightness with which it is applied, the depth of tone, the nature of the design and its adaptation to the natural figuring of the wood, and the final processes of polishing or varnishing. In some cases it may be desirable to have a faint yet perfectly discernible decorated scheme which is more particularly suitable to arabesques or floral designs ; in others, seascapes, mountain or forest scenes, pastorals and the like, a more dream-like result should be aimed at—the shadows, agreeably diversifying the surface, taking vague, evanescent shapes as the spectator moves from place to place, or light comes and goes over the surface. Treatment of this kind, it will be observed, need not interfere with any added elaboration of detail, even the hanging of pictures or placing of wall brackets (provided that has been allowed for in the scheme) or the introduction of draperies.

Cheaper veneered plywood, used as a lining for walls or ceilings, for its

physical good qualities, may be painted all over, just as used to be done with white wood panelling. In that case the plywood should receive the ordinary preliminary treatment for wood. But it will usually be found to be well seasoned and possess a fine surface.

The finishing of ceilings on different planes, one of the "modernist" ideas, has been cleverly carried out in the Shakespeare Memorial Theatre at Stratford-on-Avon, where the ceiling of the long restaurant gallery is adorned with dentil-edged "clouds" of plywood, painted ivory, arranged in a haphazard manner on the greyish-blue ground.

WOOD CARVING

Although a large amount of very fine wood carving is being done by talented craftsmen, the outlet is comparatively limited. It is rarely seen outside the houses of the few or of public buildings. But it has been, and is indeed, an important part of decoration, for which there is a constant though not a wide demand. Mr. W. Aumonier, one of the most admired practitioners of this art, in a lecture before the Incorporated Institute of British Decorators, said: "In wood carving one has to contend with a variety of woods, some of which are excellent, and some of which are hopeless. A coarse-grained or stringy wood should never be carved, as the markings are too pronounced and either distort the ornament or distract the eye from the carving. Probably one of the best woods for carving is lime tree, a firm, close-grained wood, devoid of any marking, and which, when left in its natural state from being carved, takes on a tone of its own, improving in colour as time goes on. Oak, as a permanent wood left in its own colour, is perhaps pre-eminent as a wood for carving. It is what I may call a safe wood, easy to procure in sound and free condition, and the carving—whether big or small—always looks worth its money at the finish, which is more than can be said with some of the more fanciful or darker woods. Italian walnut has a beautiful colour of its own, and is especially suitable for small or low relief work. Mahogany is a very firm wood, but the satisfactory treatment of the finished work still remains a difficult solution. The moment it is polished or waxed half the value of the carving has gone. It is a difficult question, as presuming the client desires a room carried out in mahogany, he naturally wishes the panelling polished to bring out the grain and rich character of the wood, and then the difficulty begins, having polished the surroundings, how to omit polishing the carving, and we get that unhappy compromise—wax polishing. The colour treatment of carving is a very difficult matter to decide, but I strongly advocate the introduction of a little colour amongst the carving as seen in the old Italian work. . . . A very effective form of decoration can be obtained by pierced and perforated carving. The perforations considerably augment the decorative effects of the work. Pierced carving that is going to be placed at any distance from the eye should only be very flatly carved on the surface."

Apart from modelling in the semi-round and pierced carving as above

described there are four other main ways of carrying out such work. Incised decoration is probably the oldest way of decorating, and is very effective in some positions. It consists of cutting the design in the wood by means of lines and dots. Such lines may be plain cut with the knife and done with a V- or a U-shaped gouge. Chip carving is the next in order, consisting of raised ornament in truncated pyramid form, diamonds, etc., produced by cutting away the surrounding wood, the ornament having chamfered sides. It is done with knife and chisel. In flat carving the knife and parting tool are used to cut away the superfluous wood, the design standing out in relief, but with a flat surface. It is an improved form of chip carving. Then we have inlaying, in which the design has to be traced out on the wood, the wood cut out and the void filled in with the previously carved coloured woods.

Much of the carved ornament in semi-round, being carried out in a different wood (lime, pear, or holly) than the ground, has to be fixed on the panels. If placed as a cresting there is no difficulty, but if it has to go on a flat surface it must be secured either by gluing or concealed nailing. The more satisfactory method is " planting." The carving is left with a roughly formed projecting base at the back, and a sinking in the panel corresponding to the projecttng base is gouged out of the panel, and in this the carving is glued, making a secure joint.

BUILT-UP WOOD DECORATION

A form of wood carving suggestive of plywood and flat carving has recently been introduced by the well-known decorator, Mr. C. Rebel Stanton. He produces panels, lunettes, and so on, by cutting out his designs in thin or thick layers of American whitewood, though doubtless high-class plywood would do equally well. These cut-outs often diminish in size, as he will superimpose two, three, or up to five layers, and arrange them to emphasise any part of the design. The layers themselves are kept perfectly flat, not being modelled in any way, though the diminishing sizes of the cut-outs produce an illusion of modelling. In other cases, however, the design, even if fivefold, will rise up with straight sides. The layers are glued on the sides and on each other, panel and layers having a coat of glue size, and are then painted in tempera or oils. Elaborate scenery and figure pieces can be carried out in this way.

LIGHTING

Lighting is now largely the concern of the decorator, because in addition to electroliers and wall brackets, the source of light is often concealed or screened. Moreover, light itself, sometimes tinted, is taken into consideration in the scheme of decoration for rooms used at night or when artificially darkened. Indirect lighting by electricity is generally secured by reflection from the ceiling, the electric light being concealed by a hollowed-out space in the top member of the cornice. In other cases opaque or semi-opaque shades of bowl form are placed under

pendants, generally close up against the ceiling. Such shades may be of opal or of moulded glass, white or tinted, and should be chosen to harmonise with the decorative scheme. Another method is to place the electric light between ceiling and floor, panels of glass of different shapes and colours, plain or with embossed ornament, being set flat in the ceiling, and sometimes in the floor above. The placing of lights in recesses of walls, screened with glass flush with the walls, such panels being square, oblong, or in long, narrow strips, frequently replaces the older wall brackets. Capitals of pillars and pilasters, sometimes the whole pillar, may be treated as lamps, being panelled with translucent frosted or tinted glass. Colour, substance, and surface treatment of illuminating glass are all of considerable importance to the decorator. Moulded glass, clear, clouded, and tinted, is largely used in connection with lighting schemes, both as screens in walls and ceilings and for fitments which may form an integral part of sideboards, writing-desks, dressing-tables. Oblong, oval, or odd-shaped panels, clear water-white or delicately tinted, are very useful mounted as shades on pendants, brackets, and standards, the beautiful embossed designs showing up well, and are in most positions an improvement on silk and parchment shades. Large standard lamps, often used as fixtures on mantelpieces, in alcoves, or other places, have the bodies as well as the shades made of this moulded sculpturesque glass, and then the bodies contain a small electric globe, so that a faint light can be obtained with this alone switched on, or a more powerful glow when both sources of light are in operation. In selecting tinted glass for shades the influence of the coloured light thus produced on the decorations generally must be kept in mind. Coloured light, however softly tinted, may improve or mar a colour scheme; it will always have some effect upon it, and the influence of coloured light differs from that of solid colour, say, that of paint.

FLOORS

Floors, whatever their nature, should be taken into consideration in all decorative schemes. Cement, terrazzo, and plastic floors have already been dealt with in the chapter on Interior Plastering. The actual laying of boarded floors, being carpenter's and joiner's work, need not detain us here, but other kinds of wood flooring require a few words.

Parquet Flooring is made up of small pieces, or tiles, of hardwood, cut to various shapes, so that the finished work can be very simple or quite elaborate, especially when there is a mixture of differently coloured woods. The woods most commonly used are oak, teak, and beech, thoroughly seasoned. The tiles are cut to thicknesses varying from $\frac{1}{4}$ inch to $1\frac{1}{4}$ inches. Ordinary parquet is straight-sided, and is laid in mastic. Better quality is grooved for cross-tonguing and secret nailing on wood subfloors, and dovetailed-grooved for laying on stone or concrete, to which it is fixed by refined asphalt. Plated parquet is made up of thin veneers of hardwood, especially the fine figured woods, $\frac{5}{16}$ inch thick, pressed on a

backing of 1-inch deal. Sheet parquet is made up into fairly large panels, the standard size being 2 inches square, $\frac{1}{4}$-inch parquet being backed by plywood. These panels only require nailing. Ordinary parquet is usually laid in blocks or first made up into panels, which should not, as a rule, exceed a yard square. If the sub-floor is ordinary boarding, care should be taken to nail down any loose boards, fill up holes and wide crevices, and procure a perfectly level surface. If the boards are old or of poor quality, they should (after cleaning) be creosoted. The best sub-floor is made up of narrow deal boards, 3 inches to 4 inches wide, not too thin. On ground floors, or over cellars, the underside of the sub-floor should be protected from damp. Where central heating is adopted, care must be taken to insulate all pipes carried below the floors. If the sub-floor is of concrete or cement, it should be perfectly dry, and a wise precaution is to dress the matured surface with bitumistic paint or other waterproofing material. If the parquet is to be secretly nailed on such a sub-flooring, it will be necessary to embed thoroughly seasoned, creosoted wood fillets in the cement floating. Parquet only requires wax polishing.

Tiles on Concrete have already been dealt with in the chapter on plastering referred to above. They can also be laid upon wood joists, across which strips of suitable metal lathing are stretched and fastened. These receive a top dressing of fine concrete, $1\frac{1}{2}$ inches thick, with a rendering of fine cement mortar in which the tiles are embedded. The lathing should be back plastered. There is a very wide choice in flooring tiles, providing admirable decorative material.

Rubber Flooring is of considerable importance both for private dwellings and public buildings. It is noiseless, soft to the tread yet hard wearing, and non-slippery. It is procurable in the form of vulcanised tiling, plain or inlaid with coloured designs, solid (straightedged), or interlocking. These are laid like ordinary tiles, in mastic or special rubber composition. Then there is non-vulcanised rubber carpeting, even more soft to the tread and quite flexible, made in thicknesses of $\frac{1}{8}$ inch and $\frac{3}{16}$ inch, in standard widths of 3 feet and 4 feet and rolls 100 feet long. Rubber flooring can be laid on boards or concrete. Boarding must be sound, well nailed, and levelled, protected from damp, and insulated from hot-air or hot-water pipes. Concrete must be dry, and should receive a wash of bitumistic paint. While rubber tiles and carpeting can be procured with elaborate polychrome decoration, for general service self-coloured material, in neutral tones or broken greens, blues, or dull reds are more useful, whether left plain or partly covered with rugs.

Treatment of Boarded Floors.—If floors are well laid with narrow boards of seasoned wood, all they really need is planing, sandpapering, and wax polishing. With ordinary boards, staining is very generally adopted. The first thing to be done is to clean them, which usually means the removal of paint or distemper stains, plaster, size, and paste splashes on a new work, or those and more nondescript stains on old floors. Paint,

if still wet, can be removed by scraping and rubbing in turpentine ; if harder a paint remover may be necessary, followed by scraping, rinsing with vinegar, water, or turpentine. Hot water containing a little soda will usually remove distemper, size, and paste. Plaster will require soaking and scraping. Bleaching materials will have to be applied on ink stains. When the stains have been removed the whole floor must be thoroughly scrubbed with soap and water. Loose boards must be nailed down, nail heads sunk with a punch, and these, as well as knot holes and crevices between boards, filled in with a plastic wood composition, which can be levelled with the knife and sandpapered. Old, porous boards should have crevices and holes painted with oil or turpentine before applying the wood filler to lessen suction. Very bad old boarded floors may need planing and sandpapering, especially when the surface is splintered. Wood floors when to be stained should not be sized, as it is the aim to ensure the stain sinking in, otherwise it would soon be worn off by the friction of treading. The exception is when " chemical stains " are used on very old, absorbent boards. These " chemical stains " are solutions of ammonia and permanganate of potash, or muriate of iron for oak. Ammonia gives cold browns to green browns on oak ; permanganate rich warm browns on oak or cedar, but reddish to blackish browns on ordinary deal. A 20 per cent. solution of muriate of iron gives a bluish grey on English oak, a rich blue-black on Tasmanian oak. None of these, however, is quite satisfactory, soon bleaching or wearing out, or if used strong wearing dark and dull. Finely ground dry pigments, umbers, siennas, Vandyke brown, and deep black can be mixed in size water to give a cheap, quickly applied stain. But they are not permanent. Water-soluble stains are both convenient and satisfactory. The dry powders are dissolved in water, to which a little size may be added for softwoods, and about 20 per cent. of methylated spirit to secure easy spread and penetration. Their chief fault is that they are apt to bleach under daylight. Spirit stains, soluble in spirit or spirit varnish, are fast to light. When dissolved in spirit varnish a rich colour and good surface are obtained, but penetration is poor, so they are apt to wear off. Oil stains, generally fast to light, are of several kinds : (1) dissolved in turpentine, (2) in naphtha, (3) in oil varnish. The two first have good penetration and are easy to spread. Oil varnish stains are more in the nature of paints, and though easy to apply are slow drying. They do not require varnish. When varnishing over stains, a coat of size or of knotting is advisable with old or poor-quality wood, but not necessary on harder wood. Only floor varnish should be used, and this must be well brushed in.

In some cases floors are painted with oil paints. This is usually reserved for the sides of stair treads, landings, etc., and in such cases the ordinary methods apply.

CHAPTER 8

GLAZIERS' WORK

Sheet Glass.—Glass used for all kinds of window glazing is made in five types : (*a*) sheet, crown, and antique church glass, such as is produced by pouring the molten metal on a steel table, and has a natural surface ; (*b*) rolled, cast, or pressed glass, whose face is formed during the process of manufacture, usually by passing the pliable sheet between rollers, by which the surface is smoothed or patterned by means of one of the rolls being engraved ; (*c*) glass which has its surface treated after pouring and cooling, such as grinding and polishing, frosting, etching, or enamelling ; (*d*) armoured glass, which has steel mesh incorporated in the molten mass ; (*e*) light-filtering glass. All such glass can be coloured throughout by adding tinting materials to the molten metal, or on the surface by " flashing " or " casing " with a thin coat of coloured material, while the white sheet is still hot and soft. Glass can be bent in large or small sheets to gentle or sharp curves, and even compound curves. It is possible to procure large segments of a dome for top lighting.

Ordinary window sheet glass is sent out in sheets and in " panes " or " cut squares," reduced to average working sizes. It is made in six gauges, described by weight per foot super. 15-ounce glass averages $\frac{1}{13}$ inch thick; 21-ounce, $\frac{1}{10}$ inch; 26-ounce, $\frac{1}{8}$ inch. There are also 32-ounce, 36-ounce, and 42-ounce glass, but these are seldom used except for shop-fitting and factory purposes. Sheets are made to 60 × 40 inches, but 24 inches square for the lighter glass and 40 inches square for the heavier weight are more manageable, and unless very large quantities are used, " cut squares " are more economical. After manufacture the sheets are inspected and sorted out for qualities : firsts are free from blemishes, suitable for the highest-class work ; seconds and thirds are good, but with slight blemishes ; fourths are reserved for stables, garages, workshops, or very cheap house property.

Plate Glass.—Plate glass is cast, rolled, ground to a perfectly level surface, and polished on both sides. It can be made into sheets having an area of 300 square feet. Stock thicknesses and dimensions are given in the table on page 162.

" Patent Plate," or " picture plate " is special plate $\frac{1}{4}$ inch thick made in small sheets.

Double-rolled glass is polished on both sides ; ordinary rolled is polished on one side and dull on the other, and is made in $\frac{1}{8}$-inch, $\frac{3}{16}$-inch, $\frac{1}{4}$-inch,

Thickness in inches	Size in inches.	Approximate weight per foot super in pounds.	Ordinary uses.
$\frac{1}{8}$	90 × 40	2	Ordinary window glazing.
$\frac{3}{16}$	110 × 72	$2\frac{3}{4}$	
$\frac{1}{4}$	165 × 110	$3\frac{1}{2}$	Shop fronts, table tops.
$\frac{5}{16}$	180 × 130	$4\frac{1}{4}$	
$\frac{3}{8}$	280 × 130	$5\frac{1}{2}$	Shop fronts, table tops, shelves.
$\frac{3}{8}$	288 × 168	$5\frac{1}{2}$	
$\frac{1}{2}$	180 × 120	7	Special shop-front glazing.
$\frac{5}{8}$	132 × 114	$8\frac{3}{4}$	Aquaria, floors, etc.
$\frac{3}{4}$	124 × 108	$10\frac{1}{2}$	
$\frac{7}{8}$	120 × 100	$12\frac{1}{4}$	
1	110 × 96	14	
$1\frac{1}{4}$	108 × 72	$17\frac{1}{2}$	

and $\frac{3}{8}$-inch thicknesses. Rough cast is very similar, and is made in three thicknesses: $\frac{3}{16}$-inch, $\frac{1}{4}$-inch, $\frac{3}{8}$-inch. They are used for positions where strength is required, but not absolute clearness. For moderate-sized panes in warehouses, factories, and for skylights generally, $\frac{1}{8}$-inch, $\frac{3}{16}$-inch, and $\frac{1}{4}$-inch sheets are used; where larger panes are necessary, $\frac{3}{16}$–$\frac{3}{8}$-inch. Rough cast for pavement lights, floors, etc., is made in thicknesses rising from $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches.

Rolled cathedral is about $\frac{1}{8}$–$\frac{1}{4}$ inch thick, is usually tinted, and cut up for leaded lights and fancy glazing. It includes several varieties of surface finish, starting from a slightly pitted morocco-leather type, rippled (with more defined depressions), arctic, and ending in small and large hammered glass, having a surface resembling hammered metal. Variegated cathedral glass is coloured with two broken tints, more or less of agate pattern, the most used being ruby on yellow, chocolate on yellow, blue on white, and green on opalescent.

Figured rolled is made in over a score of styles, from plain hammered pinhead, morocco, kaleidoscopic (a small stellar ornament), to elaborate floral designs, the patterns being produced during the rolling process. These are all made plain water-white and tinted. These are used where an obstruction of vision is desirable, but where some loss of light is not objectionable; the obstruction of light ranges from 17–29 per cent.

Where increased illumination is required, either fluted or prismatic glazing is used. Fluted glass, though only semi-transparent, distributes light owing to its ribbed surface. It is useful for screens, partitions, etc.; 15-ounce glass being made in sheets 55 × 36 inches or 50 × 40 inches; 21-ounce glass in sheets 65 × 40 inches or 55 × 50 inches; 26-ounce, glass in sheets 60 × 40 inches or 55 × 50 inches. Where the maximum of light distribution is desired, prismatic glass, smooth on one side with horizontal prisms on the other, should be used, whether for outside windows or interior glazing of corridors or partitions. In glazing the prisms must be kept horizontal on the inside, and pointing upwards. The sheets are made in three types, with differently formed prisms, recom-

Fig. 113.—A modern shop front with polished plate-glass window.
(Courtesy of Pilkington Bros., Ltd.)

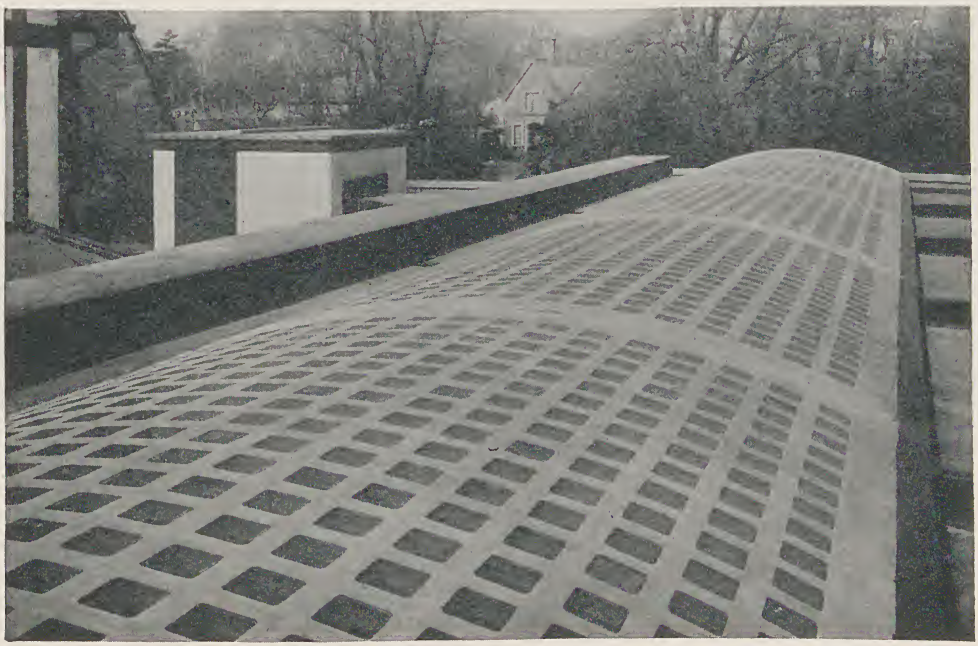


Fig. 114.—Toughened glass lenses on a roof. A. E. Eberlin, Architect.
(Courtesy of Pilkington Bros., Ltd.)

Fig. 115.—Glass-brick panels on either side of an entrance. E. I. Halliday, Architect.
(*Courtesy of Pilkington Bros., Ltd.*)

mended respectively for situations where the angle of incidence taken from the horizontal is up to 30°, where the angle is between 30° and 40°, and where the angle is over 40°.

Fancy Sheet Glass.—Sheet glass, other than plate glass, can be had rolled, which is semi-transparent, fluted, with narrow or wide corrugations; and muffled or rippled. Sanded sheet is pinheaded all over, produced by scattering hard sand over the flattening table. Cathedral sheet and specky sheet are both unbleached sheet, roughly poured and flattened, so containing bubbles, specks, and irregular surfaces. They are mostly used in leaded work. Antique sheet is tinted glass, quite clear, and with a wide range of beautiful, brilliant colours. Flashed or cased glass, white on one side, coloured on the other, is used for the same purpose; the colour when necessary can be ground or etched away to show patterns in the clear colourless glass backing. Ambeth is a variety of this class, having a wide range of colours and tints, either quite transparent or verging into the nearly opaque. Quite opaque coloured sheet and plate glass is also made, but this is for wall lining, not glazing.

Light-filtering Glasses.—A great variety of glasses are now manufactured, which contain certain minerals introduced with the special purpose of splitting up the sun rays or artificial light so as to obstruct the passage of some of these rays. The best known and most commonly used of these in ordinary glazing are the ultra-violet-ray glasses. This type ensures a free passage for these health-giving rays, which are more or less obstructed by ordinary window glass. "Vita" glass belongs to this type. It is made in clear sheets $\frac{1}{10}$ inch thick and about 60 × 40 inches; polished plate, $\frac{5}{32}$ inch thick; cathedral sheet $\frac{1}{8}$ inch thick or more, up to 8 feet long; wired, $\frac{3}{16}$ inch thick, up to 108 inches long by 24 inches wide. "Horticultural Vita," suitable for conservatories, aviaries, and poultry houses, is available both in clear and cathedral sheets. It is as powerful as the other qualities but not so perfect in texture and surfaces. Other glasses of the kind obstruct chemically active rays, and are very useful for picture galleries and the like, while others eliminate the heat rays. None of these requires any special handling, beyond the fact that they should be glazed in as large sheets as possible in order to secure the full benefit.

Safety Glass.—Safety glasses fall into two classes: the sandwich type, and the wired. The first is represented by the triplex sheets, made up of two outer sheets of glass and a thin sheet of transparent celluloid coated with special cement. Such glass, used largely on motor-cars and tramways, is very difficult to break, and will not splinter when broken. Although suitable for special glazing (for instance, jewellers' shop windows), so far it is very little used for the purpose. On the other hand, wired glass is very extensively applied in many positions. The wire mesh is embedded in the glass while it is being manufactured, so forming a homogeneous material extremely difficult to break or cut when fixed in

position, and capable of offering a considerable amount of resistance to fire. Consequently, it is of the greatest use in factories for window and partition glazing, and generally for all roof lights, especially those over conservatories or lean-to constructions liable to be damaged by dislodged slates or masses of snow falling from roofs. Wired glass is also used as an outside protection for valuable stained or painted leaded windows. A particular kind of armoured glass has rectangular wire mesh, electrically flat welded at the junction. It has a handsome appearance in plain or cathedral sheet, plain or patterned, colourless or tinted, and is known as "Georgian" wired glass. Such wired glass requires special care in cutting; the sandwiched glass cannot be cut, as the edges are sealed and cutting would interfere with adhesion.

Moulded Glass.—Moulded glass, clear or translucent, colourless or tinted, with raised decorative designs, is being much used for glazing panels of inner hall and other doors, partitions, screens, and illuminating panels. The sheets are unusually thick, and as they are ornamented with decorative designs of a floral or a pictorial character, cannot, as a rule, be cut. The glass, as well as being thick, is tough and difficult to deal with even for trimming. It is made ready for mounting as panels or quarries, very largely from individual designs, but can also be secured in a great variety from stock, both for screens and lighting.

Roof Tiles.—Flat and corrugated roofing tiles are made for use with ordinary slates or tiles as a means of securing top lighting without the use of frames. These are usually handled by the slater and tiler, rather than the glazier, as they have to be bedded and lapped. But the larger corrugated sections made for use on galvanised corrugated-iron sheet roofing are sometimes glazed in metal framing; the method adopted is the same as that with metal casements Cutting is not advisable.

Putties.—An excellent putty for glazing on wood is made by mixing 21 pounds of bolted whiting with $\frac{1}{2}$ gallon of raw linseed oil, kneaded into a stiff but plastic paste. It can be kept fresh by steeping in water. For a quick-drying facing putty, on wood or metal, mix together 16 pounds of gilders' bolted whiting, 12 pounds of floated silica, 12 pounds of sublimed white lead, 1 pound of pulverised pumice stone, 1 ounce of lampblack, 1 gallon of coach japan, $\frac{1}{3}$ gallon of mixing varnish, $\frac{1}{16}$ gallon of raw linseed oil, and $\frac{1}{16}$ gallon of turpentine. For skylights, and other positions needing a strong waterproof putty, mix together 15 pounds of bolted gilders' whiting, 5 pounds of dry white lead, 1 pound of silica, 1 pound of litharge or red lead, and $\frac{2}{5}$ gallon of raw linseed oil. For steel or other metal casements knead well equal volumes of whiting, white lead, and half the quantity each of red lead, litharge, and manganese, with enough raw linseed oil to make up a stiff paste. The Building Research Station suggest the addition of 10 per cent. of white or red lead to ordinary glaziers' putty, adding a little turpentine if too stiff, but this putty should be stiffer than that for wood. For glazing in stone mullions, use a

mastic made up by kneading 2 parts of gypsum and 1 part of litharge in boiled linseed oil. If glass sheets are placed in position temporarily use a more plastic putty, such as the one first given, but with fish oil substituted for the linseed oil. All putties must be thoroughly mixed and kneaded, and though used stiff must not be dry and crumbly.

Glaziers' Outfit.—The outfit needed for glaziers' work is not complicated. A well-made, strong, fairly long and broad table, with hard, perfectly level top is necessary. It is convenient to have one or two shelves below and a tool rack at the back or end. There must also be racks for the storage of glass sheets. For ordinary and fine cutting, diamonds in wood or horn handles are used, and for cheap work, or cutting rough-surfaced glass, either hard steel wheels or hard steel discs, also mounted in wood handles. For cutting circles and sections a beam compass fitted with a diamond set in a steel block is used. Glaziers' squares are made of boxwood with arms from 24 inches to 48 inches long, marked on both edges to $\frac{1}{16}$ inch or $\frac{1}{32}$ inch. The putty knife should be of steel, with stiff, short blade, broadening towards the point, and ending spear-shaped. For cleaning out old putty a broad-bladed hacking knife, thickened at the back, and with square sharpened end, is needed. With this should go a small wooden mallet, a small hammer with square pane, and a pair of pincers. For drilling holes a hard-tempered steel drill is used. If lead glazing is to be undertaken a brazier's outfit, with wood mallet and hardwood shaping tools, must be added.

Glass Cutting.—When about to cut glass the table top must be thoroughly cleaned, freed from putty, splinters of glass, or even dust. If a sheet is slightly hollow, place the convex part upwards. If using the diamond, hold at an angle corresponding to the slant of the head; when held too upright the diamond is worn away more quickly, while if held at too great a slope the cut will not be deep enough. The cuts should be firm, continuous, with slight pressure. Cuts should not be gone over a second time. The disc and wheel are easier to manage; the chief point with them is not to use too great a pressure, which might snap or fissure the glass, though thick glass and rough surfaces will need more pressure than a thin, smooth one. Here, too, the cut must be continuous, with no second scoring. With flashed glass see that the cut goes right through the thin coloured casing and scores the "white" backing deeply enough. When the cut is made, bring the cut line to the edge of the table and bend down sharply or leave on the table, place a boxwood rule against the cut, and bend the outer piece upwards. If the cut has been well done the glass will snap off neatly. When a circle has been scribed, make a number of straight cuts from the circle to the edges and snap off in strips. If on the other hand a pane is wanted with a circular hole in it, after scribing the circle rather deeply, score the centre crosswise, or in smaller segments if large, with the diamond, and tap these out gently with the mallet or press out with the fingers. The raw edges can be smoothed with emery powder and oil on a leather, and finished with jeweller's rouge.

Wired glass is cut with the diamond or wheel, brought to the edge of the table and bent downwards. It usually snaps off easily, cutting the wire cleanly, but if not it is easily severed with shears. All panes should be cut $\frac{1}{8}$ inch less on all sides than the opening, as a tight fit risks the shattering of the glass when putting in, or breaking as the result of contraction of the casement or vibration.

Inserting the Panes.—New woodwork should have the rebates, and the usual groove in the top part of sliding sashes, coated with good size (not painted) to stop suction, which would rob the putty of its oil and so make it crumbly and useless. Old woodwork must have all old putty hacked out, taking care to avoid damaging the wood, especially slender cross bars, and extract all brads. If the wood is poor, dry, and absorbent, it may need a coat of size followed by one of knotting. Fresh putty is pressed into the rebate and the glass pressed firmly and evenly against it. It is then secured with brads, or better still with small triangles of zinc, the point being driven into the wood and the broader part pressed against the glass. In the case of sliding sashes the glass is pushed up into the top groove, partly filled with putty, and the lower end and sides placed into the rebate. The glass is then sealed in place with putty, smoothed at an angle, to be sandpapered when dry ready for painting. Any trace of putty on the face of the glass is wiped off while fresh and soft.

Putty is not always used, even in wood casements, the panes being held in place by a beading which is screwed down ; but for external work, including windows, the beading should be bedded in red lead. Where shock and vibration have to be feared, the panes are bedded in thin strips of soft rubber, also used as cushions against the vertical face of the rebates.

Glazing in metal frames is much the same as the above, only metallic putty is used, and lead plugs, fitting into holes in the frame, replace the brads or zinc wedges. It is absolutely necessary to prevent the glass coming into contact with the metal. This can be done by the careful use of putty, though strips of wash-leather or rubber are also used for the purpose.

Patent Glazing.—For roof and all forms of top lighting a number of patent glazings are on the market. They are particularly needed in factories and workshops, where, in addition to hard weather conditions, changes of temperature, steam, and the consequent condensation have to be taken into consideration, especially as metal framing is then the rule. Most of this work is done by the manufacturers or their licensees, but many of them are handled by competent metal workers, rarely by glaziers. Most of these patent glazings are of steel sheathed in lead. In one of the most widely used, for instance, the steel bars are completely covered with jointless lead sheaths, and the glass held in place by lead flanges or rings forming part of the lead sheathing. The under parts of the bars are grooved for the collection of the water of condensation. Such joints as these are flexible, remaining watertight under the effects of expansion

and contraction caused by changes of temperature within or outside the building. The removal of water of condensation is very necessary where chemical fumes are generated, even the ammoniacal effluvia from stables and cowsheds, in order to prevent corrosion of the metal with resultant loosening of the glass panes. Another type, "King's Reinforced Concrete Glazing Bar," has a crown with a tall central projection with a lower projection each side, divided by a condensation channel. The glass sheets rest on asbestos cords in the lower projections and are pressed down from the outside by a suitable metal cap tightened by means of a screw. It can be used in most positions, though specially suitable in connection with ferro-concrete buildings.

Leaded Glazing.—For lead lights and more ambitious lead glazing cames are required, as well as steel or bronze saddle bars, or the more sightly steel-cored lead strips for supporting large, heavy windows. Ordinary lead lights for hall doors, fanlights, and stair windows can be carried out by any glazier, but stained lead glass of a more elaborate character demands skilled craftsmen with art training. In all cases, however, the methods are the same. A cartoon or plan of the window or panel is prepared, and usually coloured, showing the exact shapes and sizes of the pieces of glass to be used. These pieces are gathered together after cutting to size and shape, in the manner of a jig-saw puzzle. The glass is generally coloured, but sometimes fragments of flashed glass acid etched are included. This is "illuminated" glass. In "stained" or "painted glass" clear or tinted glasses are painted upon with fusible enamels, afterwards made fast in a muffle oven. Quite effective leaded decoration, even of a pictorial nature, can be carried out in "white" glass only, using clear and various characters of frosted and other patterned opaque or semi-opaque white glass. When all the glass has been assembled according to the cartoon, the lead cames have to be prepared. These cames are long strips of lead, sometimes with a tinned steel core, and are of an H section, the crossbar being the "heart" and the sides the "leaf." The leaf is finished in three styles, flat, round, and beaded. They are made in many sizes, with leaf from $\frac{1}{8}$ to $1\frac{1}{2}$ inches deep and hearts $\frac{1}{10}$ inch to $\frac{1}{2}$ inch long. The lead cames are cut to the required lengths, the hollows brushed with thin metallic putty, the pieces of glass inserted, and the leaf pressed down tightly on both sides. As the work proceeds, the leads have to be soldered, with fine solder containing 50 per cent. of tin. Such joints must be well seated in. The completed window or panel is framed with steel-cored cames, and reinforced if necessary, horizontally or vertically as the shape and magnitude may indicate, with saddle bars or the steel-cored lead strip. These completed panels are then treated as panes or sheets of glass to be fixed in their frames, sashes, or mullions after the usual methods of glazing, but, of course, with special care as regards security and protection against vibration, which is demanded by their great weight and comparative fragility. As already suggested, expensive illuminated glass windows can be effectively pro-

tected outside by armoured glass ; this is more sightly than a galvanised wire grille, and comes directly within the glazier's domain.

Other Coloured Glass Effects.—A cheaper way of obtaining coloured glazing effects is when flashed glass is used which can be more or less extensively etched. If the window, or upper panel of a door, is divided up into small panels, all over or by way of a border, by means of the rebated stiles and bars, a quite elaborate colour scheme can be carried out with plain or patterned coloured glass alternating with clear or etched flashed glass. This method is useful for hall doors, doors in corridors, and staircase windows, where light is required with total or partial obstruction of view. It is a cheap form of rather impressive decoration, and as such much favoured. The very large addition of coloured and figured sheet glass now manufactured makes this quite easy, but the effects depend quite as much on the joiner as on the glazier.

Details.—As most of the glazing of windows, etc., is carried out before painting and the finishing of the building, it is customary to give a large daub of whitewash on the panes, so that the fact that the windows are glazed is apparent to workers both inside and outside, and many breakages prevented thereby. It is, however, necessary to remove this whitewash on completion, which is easily done by soaking with warm water. Hardened paint stains on glass, window panes, or mirrors should have the edges scraped away with an old safety razor blade fastened in a holder, or the sharp milled edge of a coin will do. It may be necessary to soften with a little turpentine. When removed rub the spot with a rag dipped in turpentine, wash off with warm water and polish. Scratches on window glass or mirrors, if not too deep, can be removed by rubbing with a soft pad dipped in a paste of jewellers' rouge. If stained or other leaded glass has to be cleaned, dissolve ½ pound of pure-oil yellow soap, well shredded in ½ gallon of boiling water ; when quite dissolved dilute with 1½ gallons of cold water. Wash the windows with this both inside and out, using a soft brush or leather. Dry. If necessary polish with precipitated chalk or fine tripoli, taken up on a chamois pad, and brush off. It is necessary to avoid using alkaline or acid pickles, as these would attack the cement used in the cames and also attack the glass. The polishing material must be free from any suspicion of grit, as scratching must be avoided.

CHAPTER 9

PREFABRICATED CONSTRUCTION

In normal methods of construction the structure is site-built. The building is, in fact, made on the site, and chiefly made by hand. But this does not mean that everything in it is hand-made—it only means that the site work is chiefly done by hand. The units of which it is constructed are practically all machine-made in factories. These units include bricks, tiles, constructional steelwork, timber joists and boards, doors, windows, fireplaces, gas and electric fires, stoves, glass, sinks, baths, w.c.s, cisterns, and so on. There is hardly anything you can name in a modern building, from a screw to a door or window, which is not machine-made. This applies to things which were formerly hand-made as well as to purely modern materials and fittings which could only be produced by machinery. For example, doors used to be hand-made, and it is not so many years since the doors were made by a local joiner specially for the individual building.

Semi-prefabrication.—In some things the manufacturing process has been carried a stage further by assembling certain parts and thus saving site assembly. Door sets are obtainable, consisting of door, door lining or frame, the door being complete with lock and furniture and hung to the lining. The assembly is simply placed in position in the door opening and the lugs built into the wall. The combination grate is another example of factory assembly—the old-fashioned range was made in separate parts which had to be built together on the site, and it required some skill to do this.

Obviously this sort of pre-assembly or semi-prefabrication is very useful. Such work can be better done in the factory, and the standard of workmanship is likely to be higher and more consistent. The system has recently been extended to cover heating and hot-water equipment for small houses. But this is a long leap forward and we immediately strike some snags. Such an assembly cannot be used in any kind of building, nor in any kind of house. The house must be planned to suit the assembly. But it is very useful when big housing developments are planned, as the factory manufacture of complete units saves a lot of time on the site. Nor is it solely a matter of time-saving, as such a unit as that illustrated in Fig. 112 is of a much higher standard of design—scientifically and practically—than the average small house heating and plumbing arrangements, and shows a considerable saving in fuel costs.

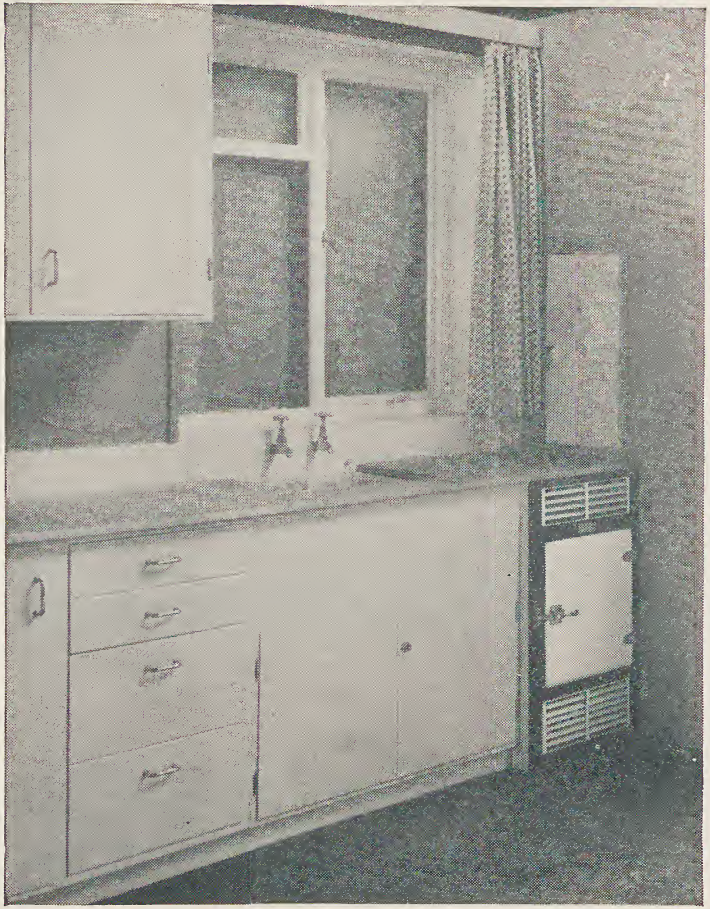


Fig. 116.—Standard built-in kitchen units.
(*Courtesy H. Newsum, Sons & Co., Ltd.*)

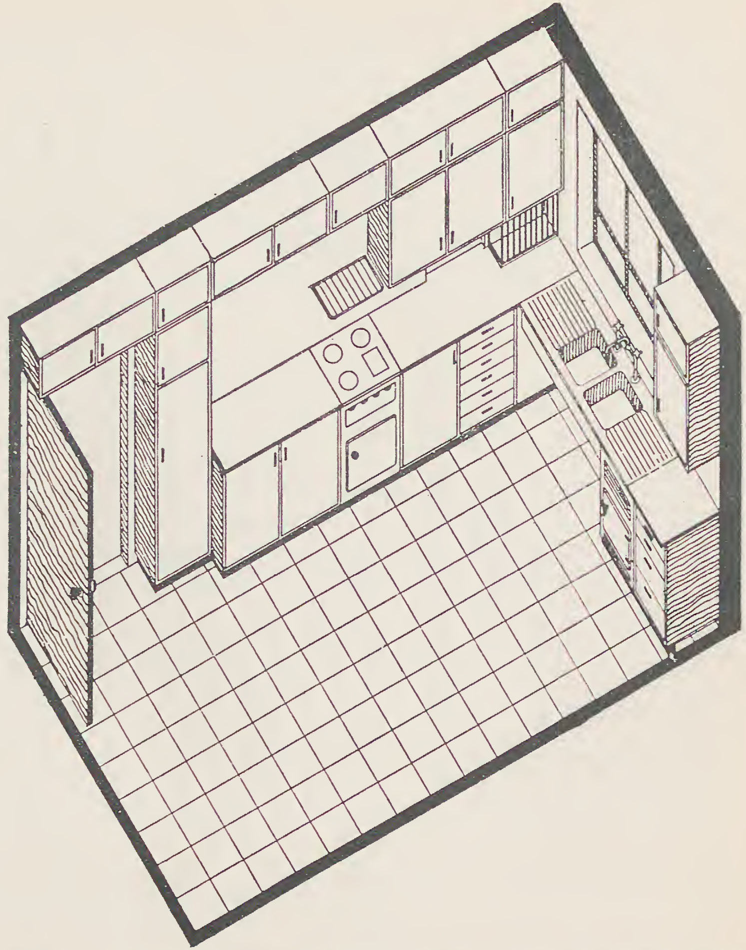


Fig. 117.—The EJMA range of kitchen units is designed to give a work top 3 feet high, wall cupboards 13 or 18 inches above this top, with dead storage space above to make up the remaining ceiling height. Large or small, new or old, any kitchen can be equipped with an efficient and unified arrangement.

For small houses, other large prefabricated units now made include: bedroom wall units containing built-in wardrobes which are placed in position instead of a normal partition; sink, draining-board and cupboard units, and built-in cupboards and dressers for kitchens; bath and lavatory basin assembly ready for connecting to waste pipes; staircases.

There are also standard ranges of steel and wood windows manufactured to British Standards by all firms belonging to certain trade associations (see Chapter 9, Vol. III). Thus we have gone a long way on the road to prefabrication, even for what we consider to be normal methods of site construction.

Essentials of Prefabricated Construction.—In full-prefabricated construction the structure itself—including walls, floors, partitions, ceilings, and roofs—is made in the factory. But there are two main divisions in prefabricated construction:

1. Factory-produced units which can be easily handled, transported, and assembled on the site.

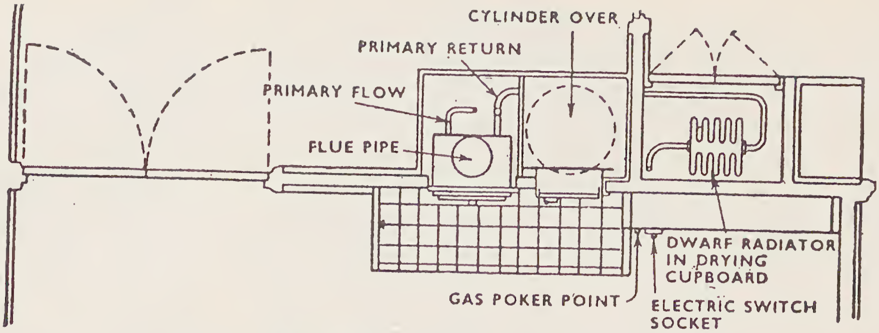
2. Factory-produced units which are assembled in the factory to make a whole house or half or quarter of a house, and then each section is transported on a special vehicle to the site, where it is placed on prepared foundations.

Method 1 has the advantage of flexibility. The building can be planned specially and the rooms can be any size which are multiples of the module or unit dimension on which the wall, floor, and roof sections are made. If the module is 3 feet 4 inches, for example, the building can be designed on paper which has been laid out as a grid of 3-foot 4-inch squares. The module is important because it must allow windows and doors to fit in. With a module of 3 feet 4 inches we may have an opening for a door 3 feet 4 inches × 6 feet 8 inches. Or for a window 6 feet 8 inches wide × 3 feet 4 inches high. Just as in brickwork construction we plan room dimensions and door- and window-openings to multiples of 9 inches (the length of a brick and a joint), so in prefabricated construction by Method 1 we plan these things to be multiples of the module.

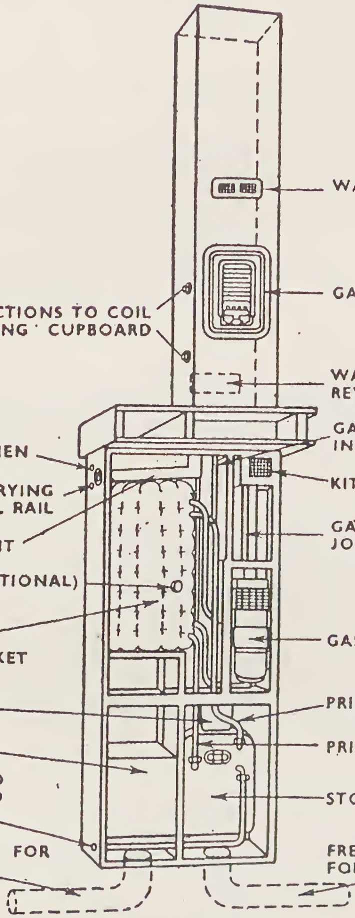
But by Method 1 the sections have to be assembled on the site. This may take from a few days to a fortnight, according to the size of the building and the method of assembly.

By Method 2 the site work is greatly reduced—in fact, almost eliminated—and the building may be placed in position, the sections fitted together, and the service connections made, in a few hours. The disadvantage of this method is the awkward problem of transporting very large sections any distance. For this reason it has not been much used except for small temporary bungalows.

It may be noticed here that prefabricated buildings are of dry construction, whereas traditional buildings are of wet construction. Prefabricated buildings thus avoid one of the chief disadvantages of traditional buildings—the delay caused by the drying-out period, which may be six months or more, and is never less than three months.



SECTIONAL PLAN THROUGH HEAT SERVICE .UNIT, TYPE 1E HOUSE



VIEW OF COMPLETE HEAT SERVICE UNIT WITH PANELLING OF GROUND FLOOR SECTIONS REMOVED

Fig. 118.—The Ministry of Works heat-service unit (patented).

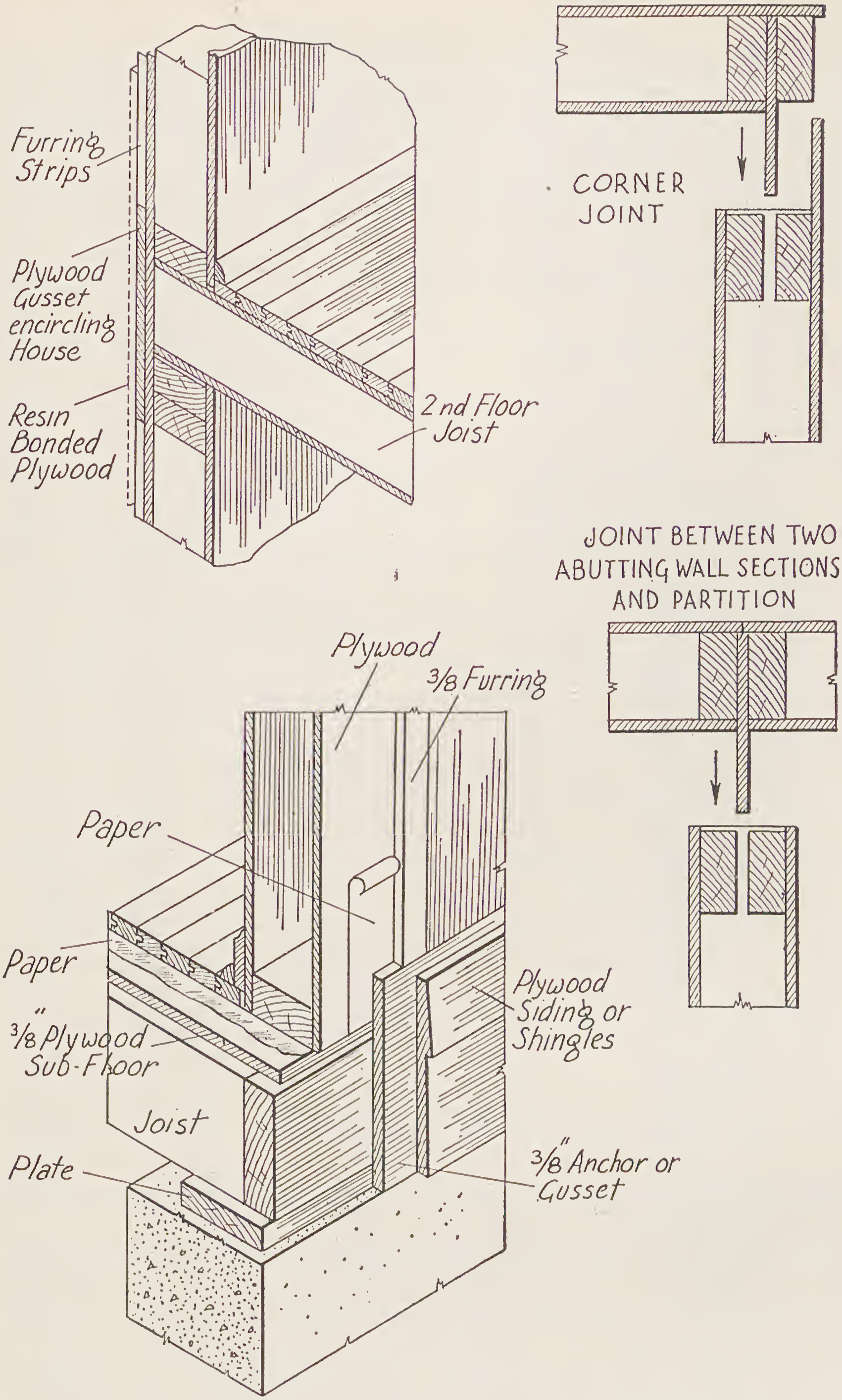


Fig. 119.—D.F.P. Dry-built house. Details of prefabricated timber construction.

MATERIALS AND METHODS

There is a wide variety of materials and methods suitable for prefabricated systems of construction. Structurally, there are two chief methods:

1. Column and panel, the columns or piers taking the roof and floor loads and transferring them to the foundations.

2. Load-bearing walls and stressed skin, the wall sections taking the loads.

For the former, strong materials must be used for the columns or piers.

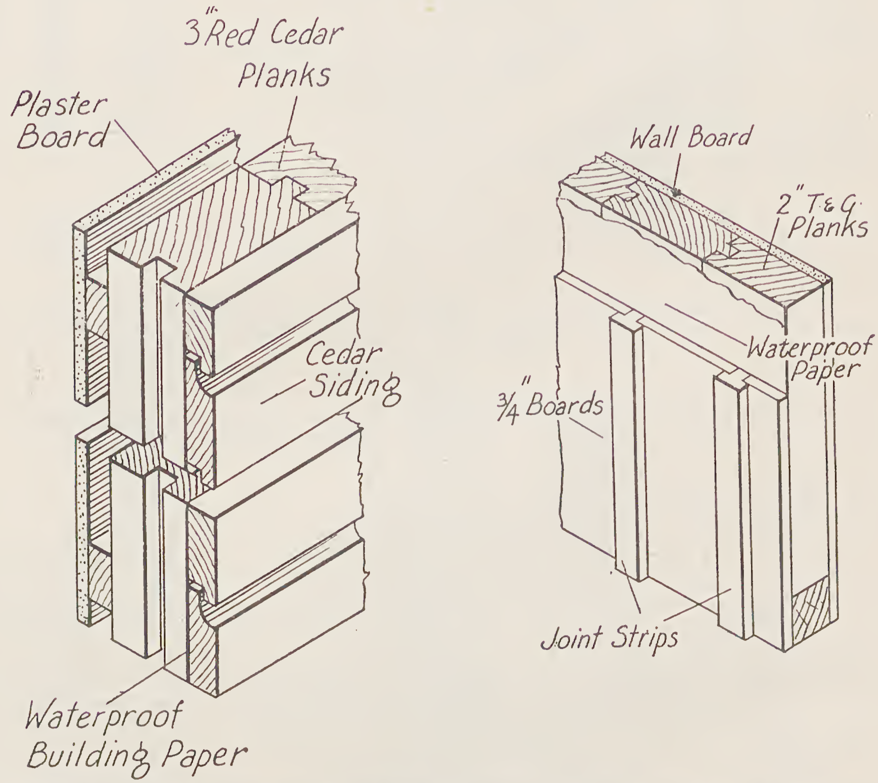


Fig. 120.—(*Left*) Tarran method (solid cedar houses). (*Right*) Swedish (Scano) system. (*Courtesy The Timber Development Association.*)

The principal materials for this purpose are: pre-cast reinforced concrete, timber, steel, aluminium alloys.

Panels need not be strong when they are used as in-filling and do not bear loads. Thin pre-cast concrete lightly reinforced, resin-bonded plywood, asbestos-cement sheets, timber boarding, rust-proofed steel sheets, aluminium-alloy sheets, are suitable for exterior cladding. For interior lining: fibre-board, hardboard, sheet plastics, asbestos-cement, plasterboard, plywood, are used.

Timber Buildings.—Prefabricated sectional timber buildings (houses, bungalows, recreation halls, garages, offices, and small sheds) have for

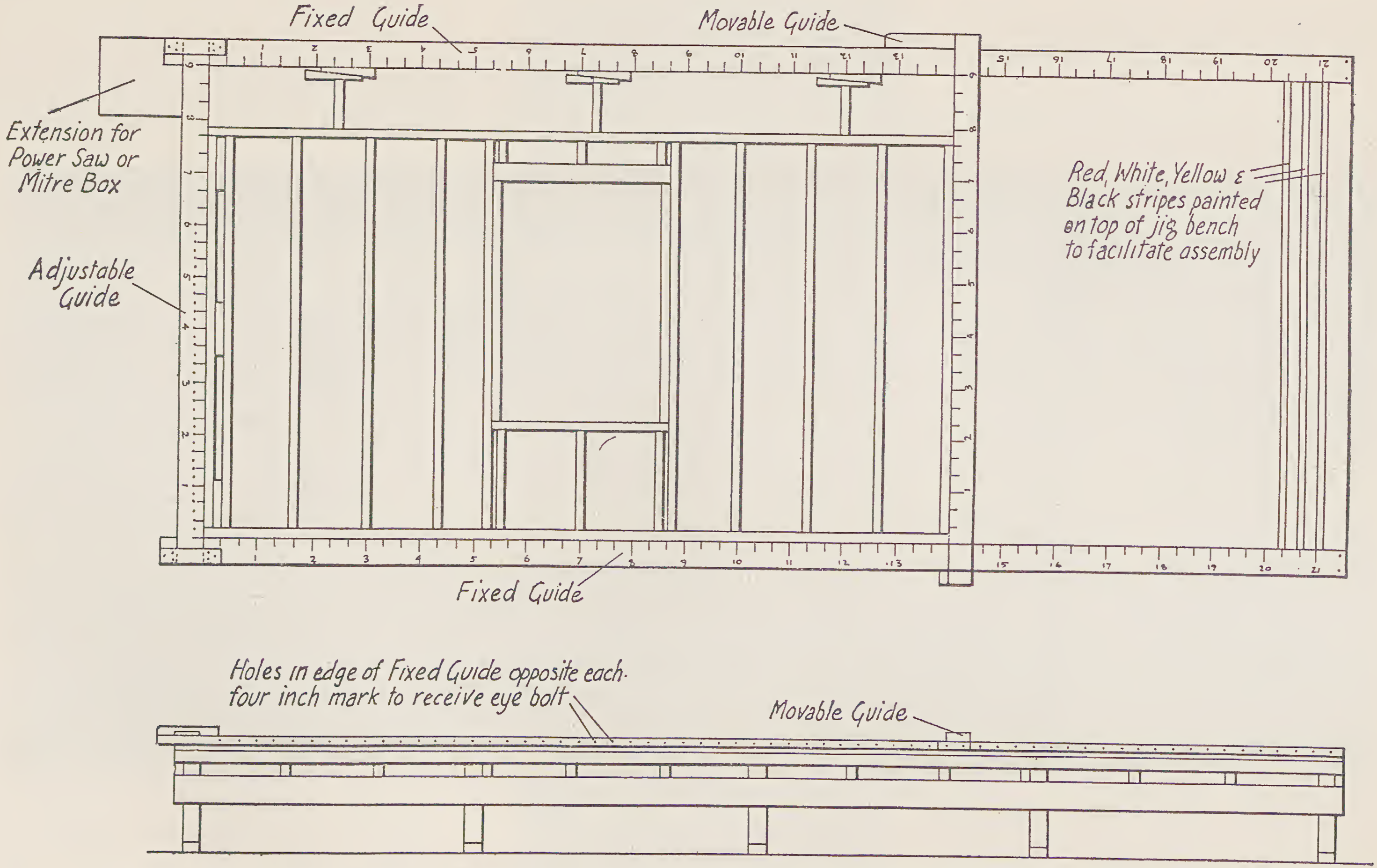


Fig. 121.—Jig table as used by the Homasote Company of America. (*Courtesy Timber Development Association*

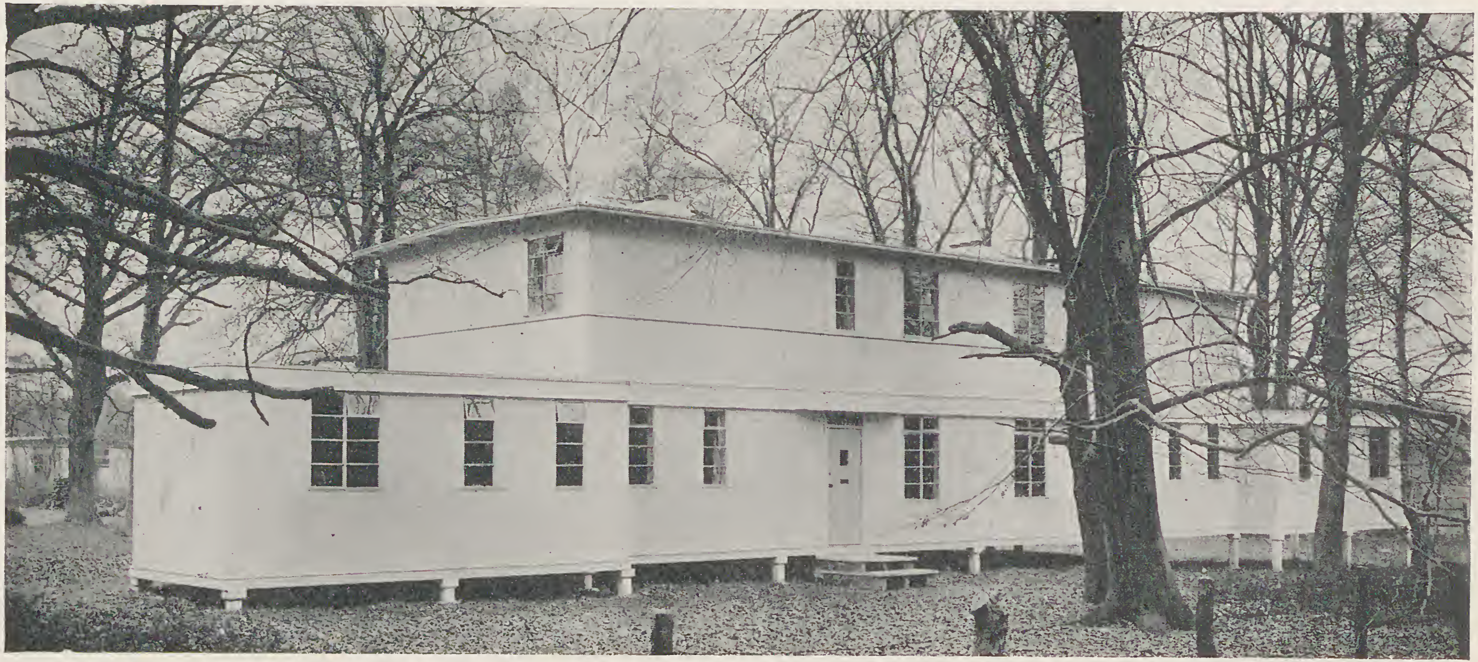


Fig. 122.—A pair of " Seco " prefabricated houses. The wall and roof units have a core of insulating material faced both sides with asbestos-cement sheets. Beams, columns, and eaves are built up of resin-bonded plywood.

many years been made in America, Scandinavia, Central Europe, and Britain. In this country the standard of construction and design has been rather poor in most of the smaller buildings, so that the public associate timber construction with light temporary buildings. In America and on the Continent the standard has been much higher, chiefly because timber has been widely used for permanent houses.

The better timber buildings in Britain have hitherto been site-built, but a few hundred prefabricated timber houses have been imported from Sweden and America and are giving satisfaction to the occupants. Those erected before 1939 have been inspected and favourably reported on by a recent Government committee.

In damp, unventilated situations, timber is liable to be attacked by dry rot. By sound structural design and reasonable protection by painting, this trouble can be avoided. There is one wood—North American

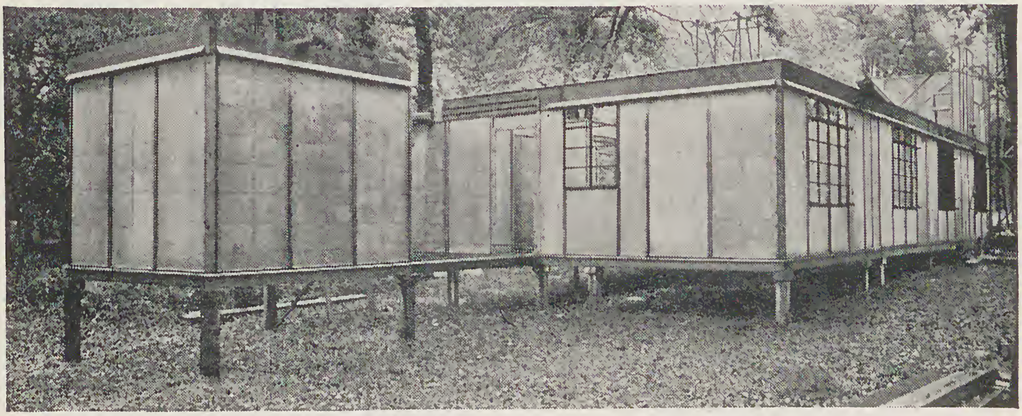


Fig. 123.—" Seco " prefabricated houses—erection of ground-floor walls.

cedar—which contains natural preservatives and is practically rot-proof. This is used for framing, boarding, and roof covering in the form of shingles. It weathers to a pleasant silvery grey and does not need painting.

The most common type of prefabricated timber construction consists of framed and clad sections which are bolted together on the site. Framing is usually 4 × 2 inches with double-skin boarding on the outside and fibre-board or plywood on the inside. In most cases the inside sheeting is fixed on the site after the sections have been erected, though there are exceptions.

The double-skin outside boarding consists of an under skin of plain boarding nailed diagonally to the framing. The outer skin consists of horizontal weather boards with lapped joints or vertical boards with strip-covered joints. Waterproof building paper or underfelt is interleaved between the two skins. This makes a strong weather-tight wall,

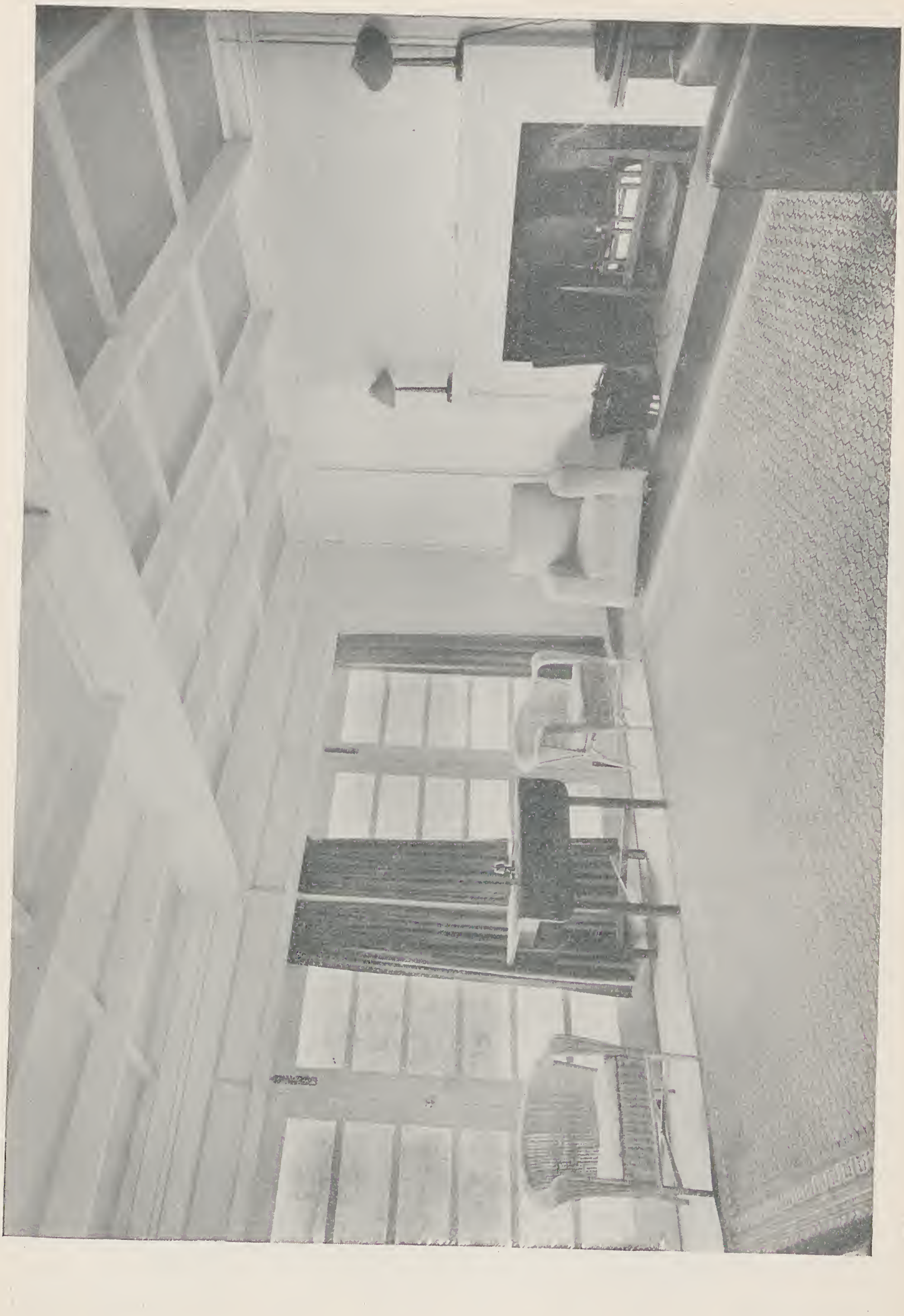


Fig. 124.—Interior of a " Seco " prefabricated building.

and the thermal insulation is superior to that of a 9-inch brick wall, but the system is rather costly.

Recent systems of prefabricated timber construction employ lighter framing. The outer cladding may consist of resin-bonded plywood, or a double skin—plywood for the inner skin and boards for the outer. In others the wall unit has a solid core of 2-inch or 3-inch planks, grooved and tongued together, sheeted with fibre-board or plywood on the inside and boarding on the outside, with waterproof paper interleaved between core and boarding.

Future developments are indicated in which lighter forms of construction will be used; plywood as "stressed skin" with light insulation

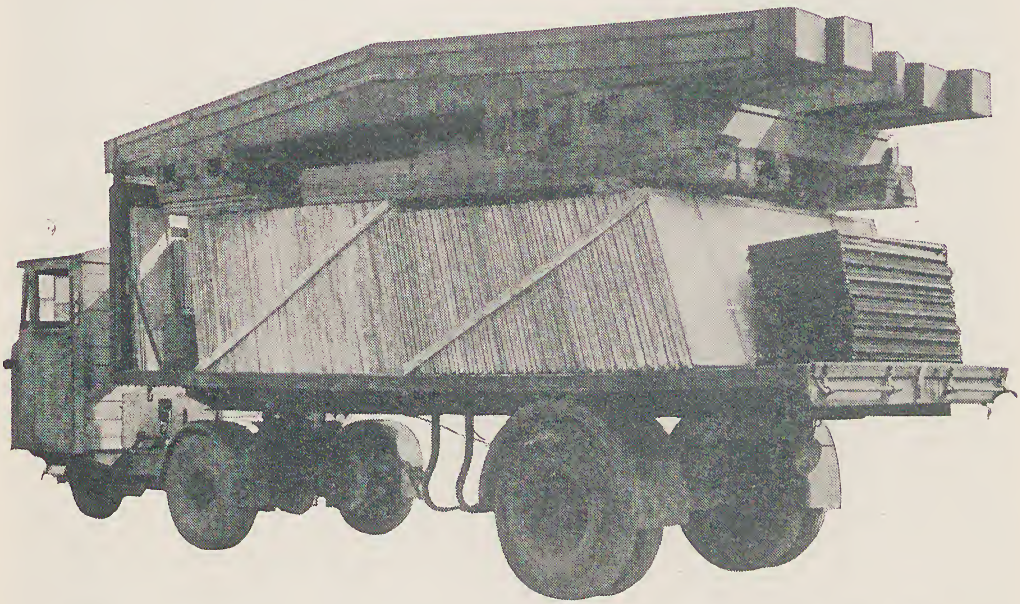


Fig. 125.—Material for a "Seco" hut, 60 feet × 19 feet. Total weight less than 8 tons.

material packed in the cavity. Wood, by the way, is an excellent insulator in ordinary board thicknesses. A 1-inch thickness is quite as good for thermal insulation as 9-inch brickwork, though not so good for sound insulation.

The fire risk in a properly constructed timber building is not much higher than in one of normal construction. Reasonable fire breaks between buildings are necessary, and in semi-detached houses the party wall should be of fireproof material.

PRE-CAST CONCRETE

Some excellent systems of prefabricated construction have been devised in recent years, especially for bungalows and other one-floor

buildings. This material has the advantage of being unaffected by damp, so that rot and rust are absent and no protective coatings are required. Ordinary concrete is a dense and heavy material which makes it cumbersome and costly to transport if used in normal wall thicknesses. But the problem of weight has been largely overcome by two means: first, by producing thin reinforced panels or hollow sections of strong dense concrete; and second, by the use of light-weight concretes which,

Fig. 126.—Making joint of " Seco " wall weather-tight with mastic. A special gun is used for this purpose.

being very porous, have to be covered with a denser material for weather protection.

Condensation is a problem in using dense concrete, but with suitable insulation this is easily overcome. Light-weight concretes having an open texture do not encourage condensation.

The two main methods of construction are used in pre-cast walling: post and panel, and load-bearing sections. For houses various post and panel systems are used, as the posts facilitate speedy erection and enable roof and upper floor to be fixed before the panels are fixed.

The B.C.C.F. System.—This system has been designed by the British

Cast Concrete Federation, an association of more than 200 manufacturers of cast stone and concrete products.

Single-storey Housing.—A system of construction for permanent single-storey houses has been devised by the Federation which can contribute substantially to the future housing programme. The system, which is eminently suitable for mass production, provides a framed outer structural shell of pre-cast reinforced concrete made up of columns and beams with pre-cast concrete in-filling panels which will support a roof of any normal type. Wall linings and other finishings and fittings

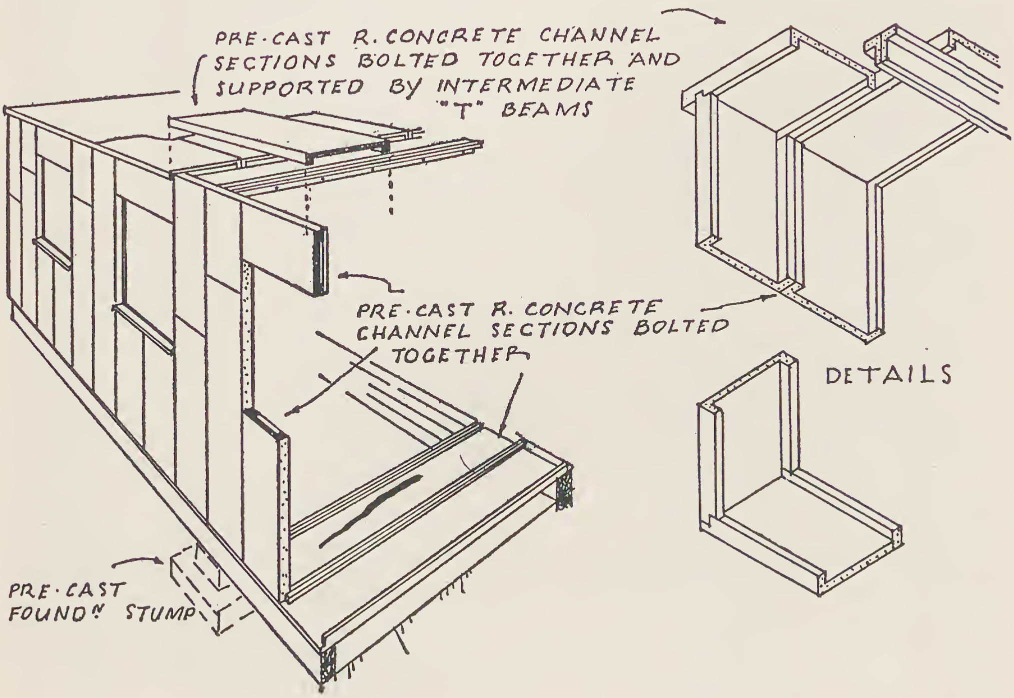


Fig. 127.—Light pre-cast concrete units for small buildings.

are independent of the structure and can be carried out in any suitable materials that may be available. The freedom afforded internally, together with the provision made for various column spacings and for forming return angles, gives the system flexibility and makes any desired planning arrangement possible. No special plant is required for the erection, which can be undertaken by any competent building contractor. Apart from housing, the system is also applicable to other types of single-storey building, such as nursery schools, assembly halls, school canteens, etc.

Details.—Foundations.—An *in situ* concrete strip foundation is laid below the perimeter walls and is increased to form column bases.

Holding-down bolts fitted in barrel sleeves allow for adjustment and are positioned by jigs and cast in.

Columns.—Columns, spaced at 5 feet 6 inches or 6 feet centre to centre, are bolted to the foundation concrete. Slots in the columns provide special fixing for the walling units. Timber fillets are cast in where required for fixing interior finishings. Columns to form internal as well as external return angles are available.

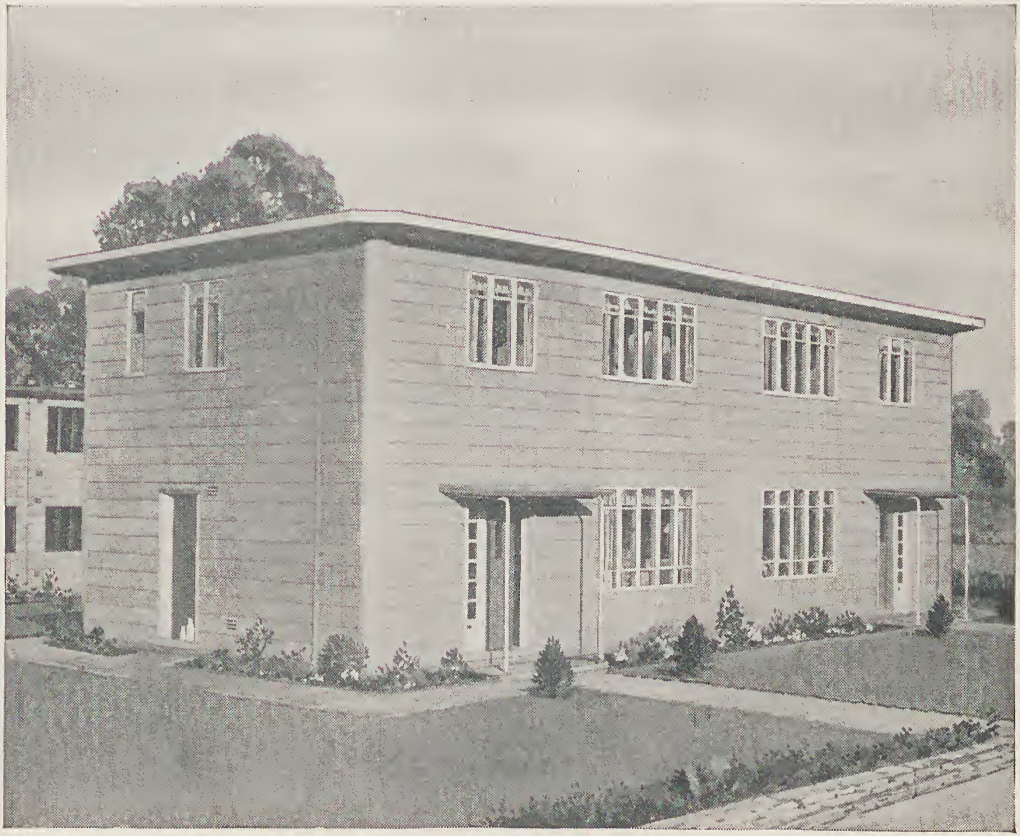


Fig. 128.—A pair of "Airey" prefabricated concrete houses.

Cill Plate.—Cill units laid between the columns form a base for the walling, and are bedded on cement mortar on the foundation concrete.

Walling Units.—Standard walling units have $1\frac{1}{4}$-inch thick panels with 4-inch flanges all round. Units to receive standard metal windows are made for one, two, or three light types. The horizontal edges of all units are weathered and bedded in mastic. The units have inclined slots in the flanges coinciding with vertical slots in the columns through which $\frac{3}{8}$-inch non-ferrous metal rods 10 inches long are passed and the fixing made by a special wedging action. The fixing is simple, effective, and

quickly made. The units are bedded against the columns in mastic. Scrim, soaked in cement slurry, is inserted into the external vertical joint between the walling units, and the column and the joint finished with mortar pointing. Where doorways occur these can conveniently be framed into a panel unit of material other than concrete to occupy one whole bay.

Eaves' Plate.—Eaves' plate units, designed to support the weight and

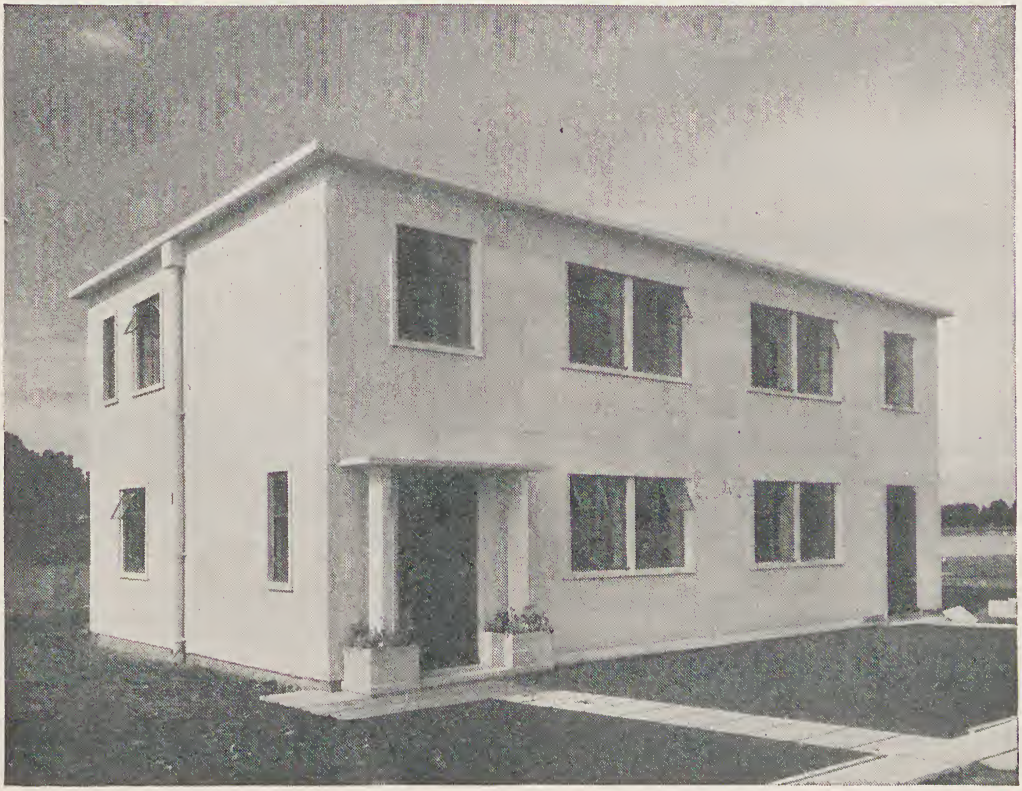


Fig. 129.—The " Orlitt " prefabricated house. Pre-cast concrete units.

thrust of the roof, connect and are bolted to the columns. Holes or plugs for fixing a timber wall plate are provided.

Roof.—The roof can be constructed of timber for a covering of tiles, or with trusses for asbestos-cement or other types of roofing sheets on purlins. Alternatively, a roof of concrete construction which has been specially designed for the system can be used.

Wall Linings and Partitions.—The internal wall linings and partitions can be of clinker or other light-weight concrete, hollow tile blocks, wood-wool slabs, or other similar materials. Alternatively, they may be of the prefabricated panel type.

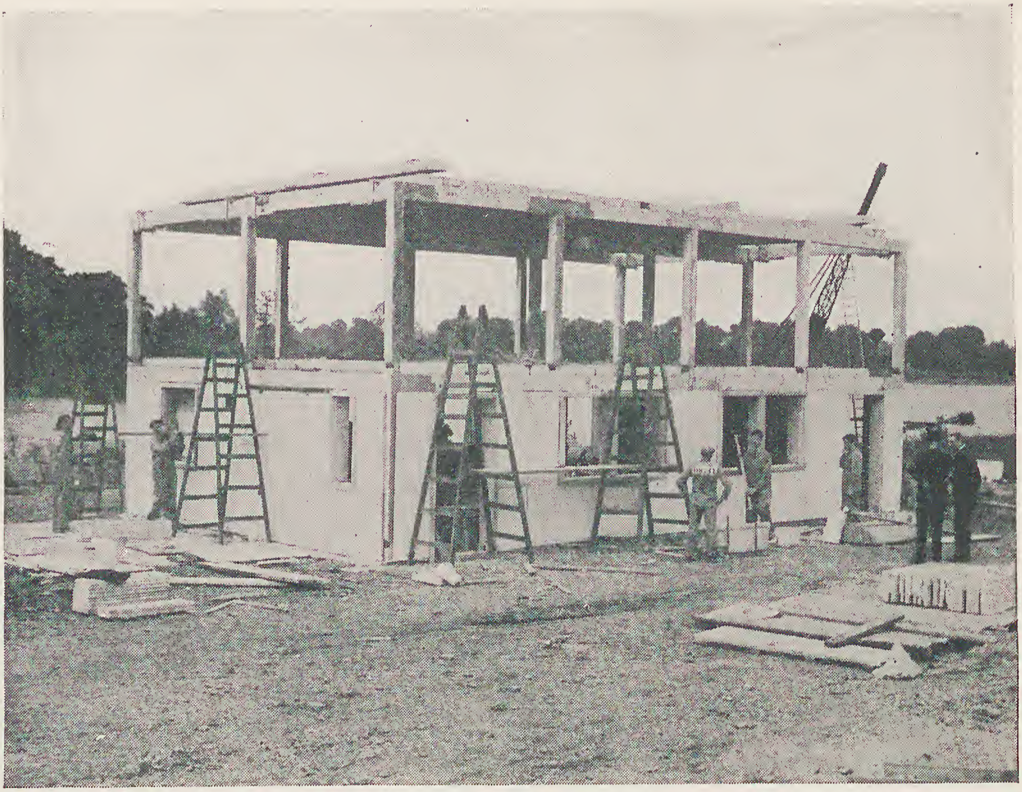


Fig. 130.—The "Orlitt" house in course of construction.

The heat transmittance coefficients for the walling with various types of inner linings compare as follows:

Values of "U" as recommended by the Burt Committee = 0·200

Values of "U" for 11-inch brick wall with an unventilated cavity . . . . = 0·30

Values of "U" for $1\frac{1}{4}$-inch Portland cement concrete panel with a lining of 3-inch clinker slabs plastered (one air space) . . . . = 0·28

Values of "U" for $1\frac{1}{4}$-inch Portland cement concrete panels with a lining of fibre-board and plaster-board pressed on to either side of a timber framework (thus giving two air spaces) . . . . . . = 0.207

Values of "U" for $1\frac{1}{4}$-inch Portland cement concrete panel with a lining of 2-inch wood-wool slabs plastered. = 0·176

Production.—The pre-cast concrete units for the system are made under factory conditions and manufacture can be carried on throughout the year. Demands which cannot be met by the output of works in any one locality can be fulfilled from other districts.

Demonstration Bungalow.—The system of construction was submitted to the Burt Committee of the Ministry of Works, who gave permission to build experimental bungalows. The first of these (sponsored by Messrs. Norcon, Ltd.) is now completed at Penn, Wolverhampton, to designs prepared by Duncan Thomson, A.I.A.A., and demonstrated the method of construction and its flexibility. It has a superficial area of 948 feet inside the wall linings, but could have been planned to meet the present maximum of 930 superficial feet for single-storey houses.

A light mobile hoist was used in the erection of the pre-cast concrete units, which was completed by 10 men in $1\frac{1}{2}$ days, representing 149 site man-hours. On normal sites where a number of bungalows are being erected it is estimated that this might be reduced to 100 site man-hours with 25 per cent. skilled labour.

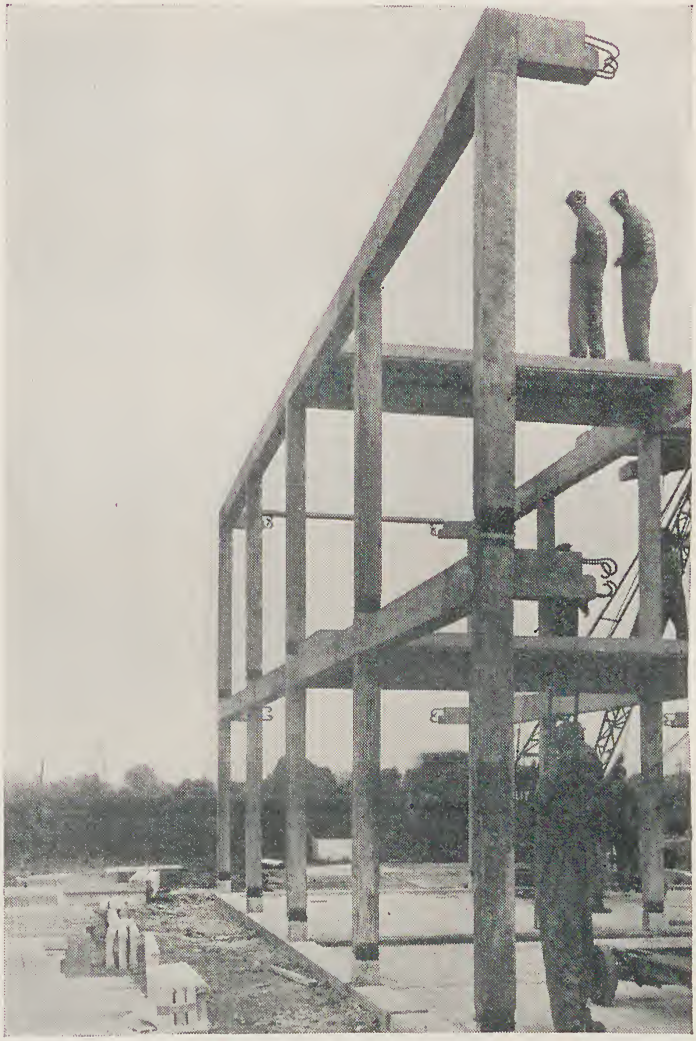


Fig. 131.—The " Orlitt " house, showing frame units.

The roof is of normal timber construction with roofing felt and concrete pantiles on timber battens. The completed structural shell and roof gave protection for the remaining work, which was carried forward without fear of interruption by the weather. The wall linings are of 3-inch clinker blocks plastered, leaving an air space between them and the concrete walling units. Together they form a $9\frac{1}{2}$-inch thick external wall with a slightly higher thermal insulation value than an 11-inch unventilated cavity brick

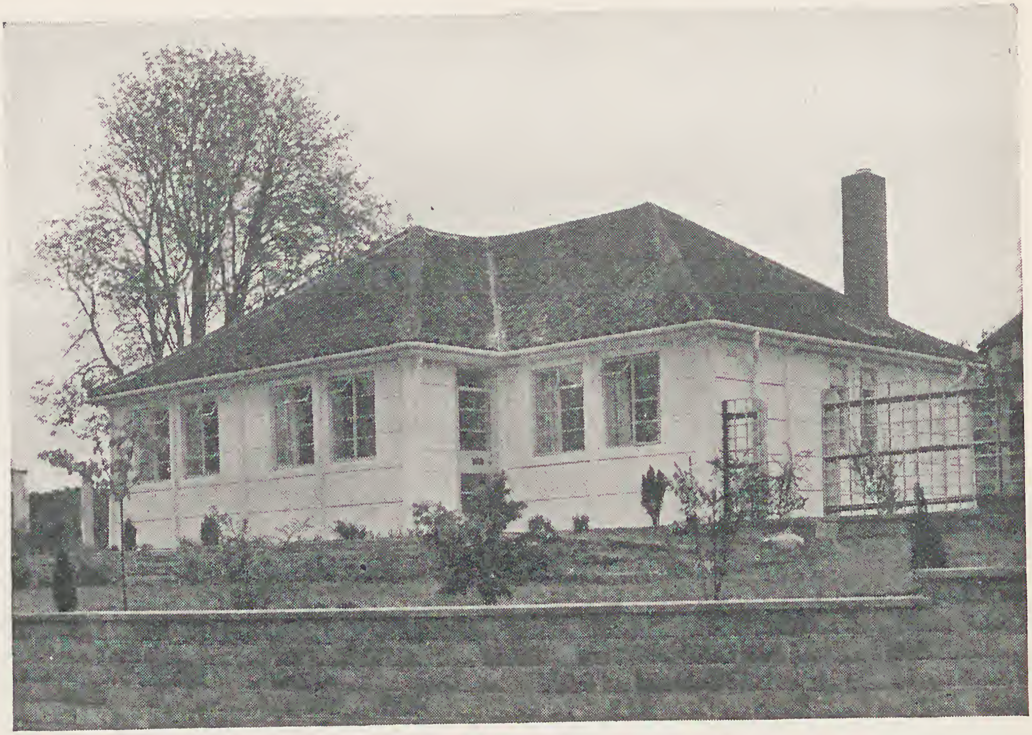


Fig. 132.—The B.C.C.F. bungalow.

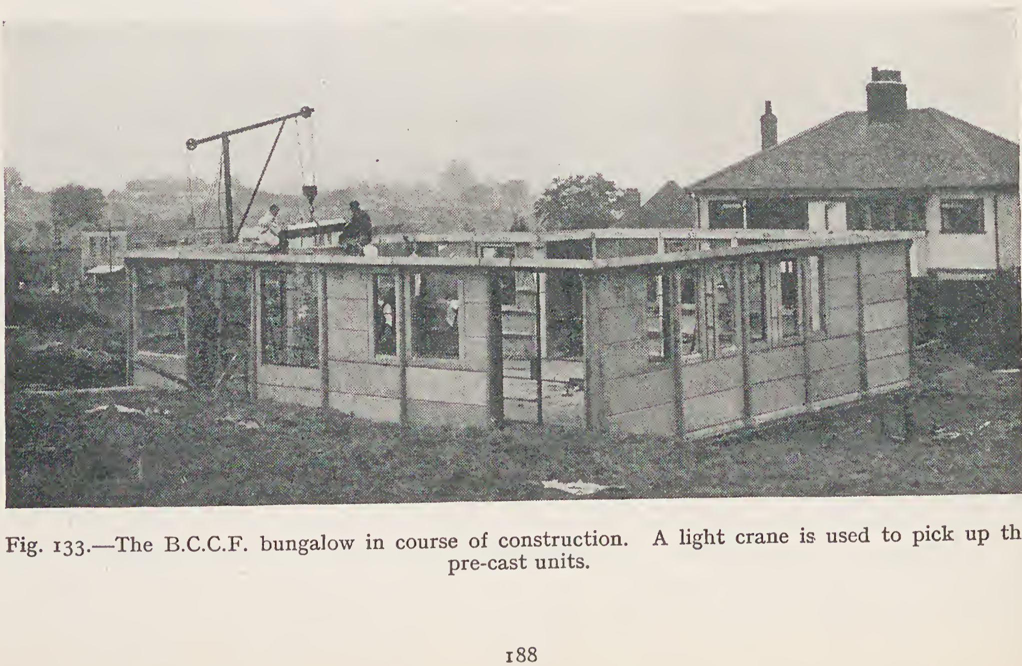


Fig. 133.—The B.C.C.F. bungalow in course of construction. A light crane is used to pick up the pre-cast units.

wall. The partitions are 3-inch and 4-inch thick clinker blocks plastered. Ceilings are plaster-board, skim-coated.

In situ concrete 4 inches thick over site was covered with a $1\frac{1}{4}$-inch waterproofed screed to receive the floor finishing.

Finishings.—The walls of the bungalow are treated externally with two coats of " Snowcem."

Oak blocks are used to all floors except in the bathroom, w.c., and part of the kitchen, where quarry tiles are used.

The walls internally are decorated with cement paint or wallpaper.

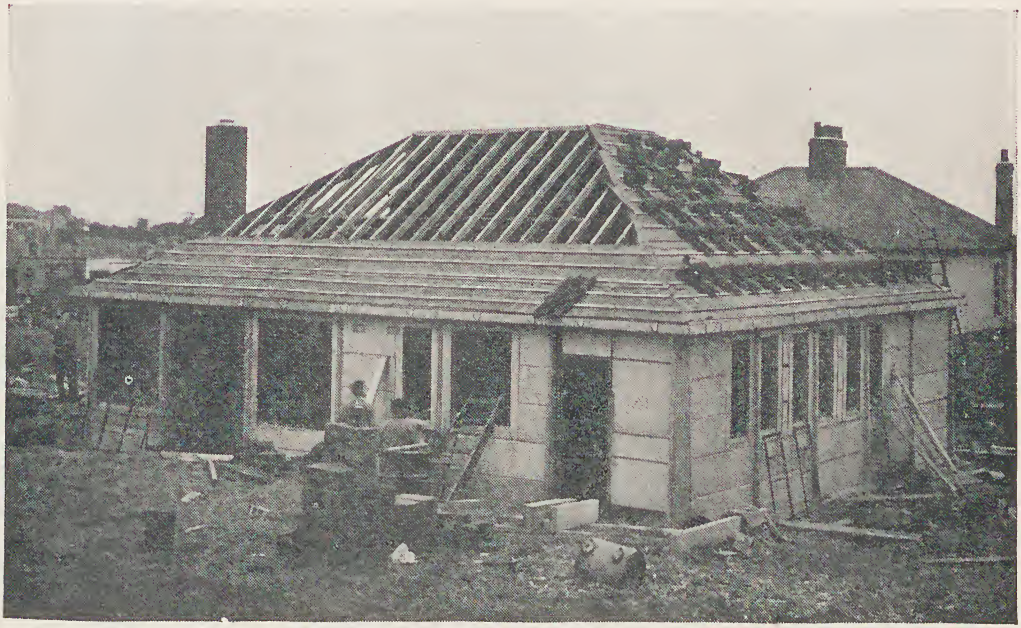


Fig. 134.—The B.C.C.F. bungalow. Construction of the roof immediately follows the completion of the structural shell.

The kitchen, bathroom, and w.c. have a special washable wall covering. The nursery walls are covered with a patterned washable wall covering to dado height and cement paint above.

Plastic washable splash-back panels are fitted in bathroom and kitchen.

Fittings.—The kitchen is equipped with :

Ventilated larder with glazed concrete shelves.

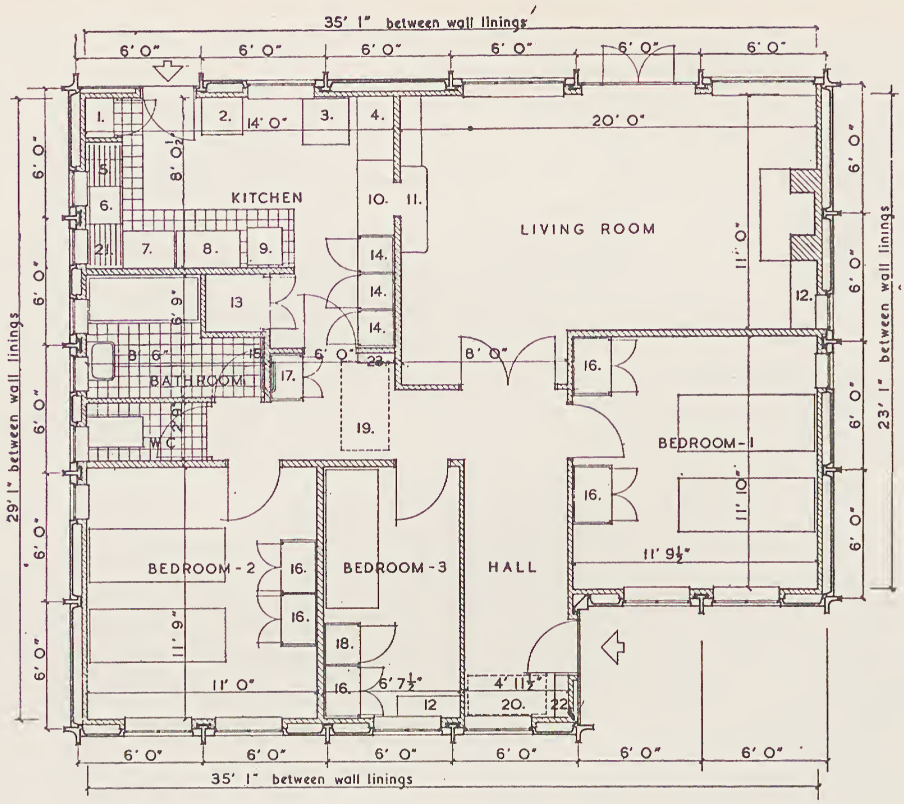
Sink unit with draining-boards, plate rack, and garbage container under sink.

Preparation table.

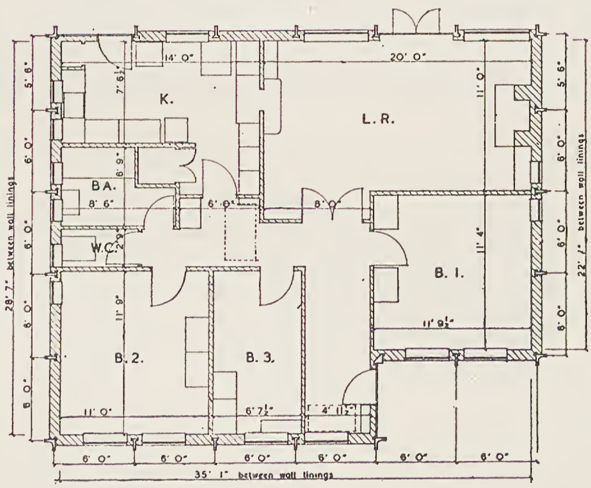
Electric washing machine.

Electric cooker of new design with oven at raised level to save stooping, and steel drawers under for saucepans.

Boiler of improved pattern to provide for easy cleaning.



PLAN 948 SQ. FT.



PLAN 930 SQ FT

REFERENCE

1. Ventilated cupboard.
2. Electric refrigerator with cupds. over.
3. Meal table.
4. Built-in seat with cupboards.
5. Draining board.
6. Sink.
7. Preparation table.
8. Cooker.
9. Boiler.
10. Table with hatch.
11. Built-in sideboard.
12. Shelving.
13. Plumbing unit.
14. Storage cupboard.
15. Towel rail.
16. Wardrobe.
17. Airing cupboard.
18. Clothing cupboard.
19. Trap-door.
20. Pram space.
21. Washing machine and wringer.
22. Meter cupboard.
23. Loft ladder.

Fig. 135.—(*Top*) Plan of the B.C.C.F. bungalow as built. (*Bottom*) Similar plan (reduced scale) of 930 square feet

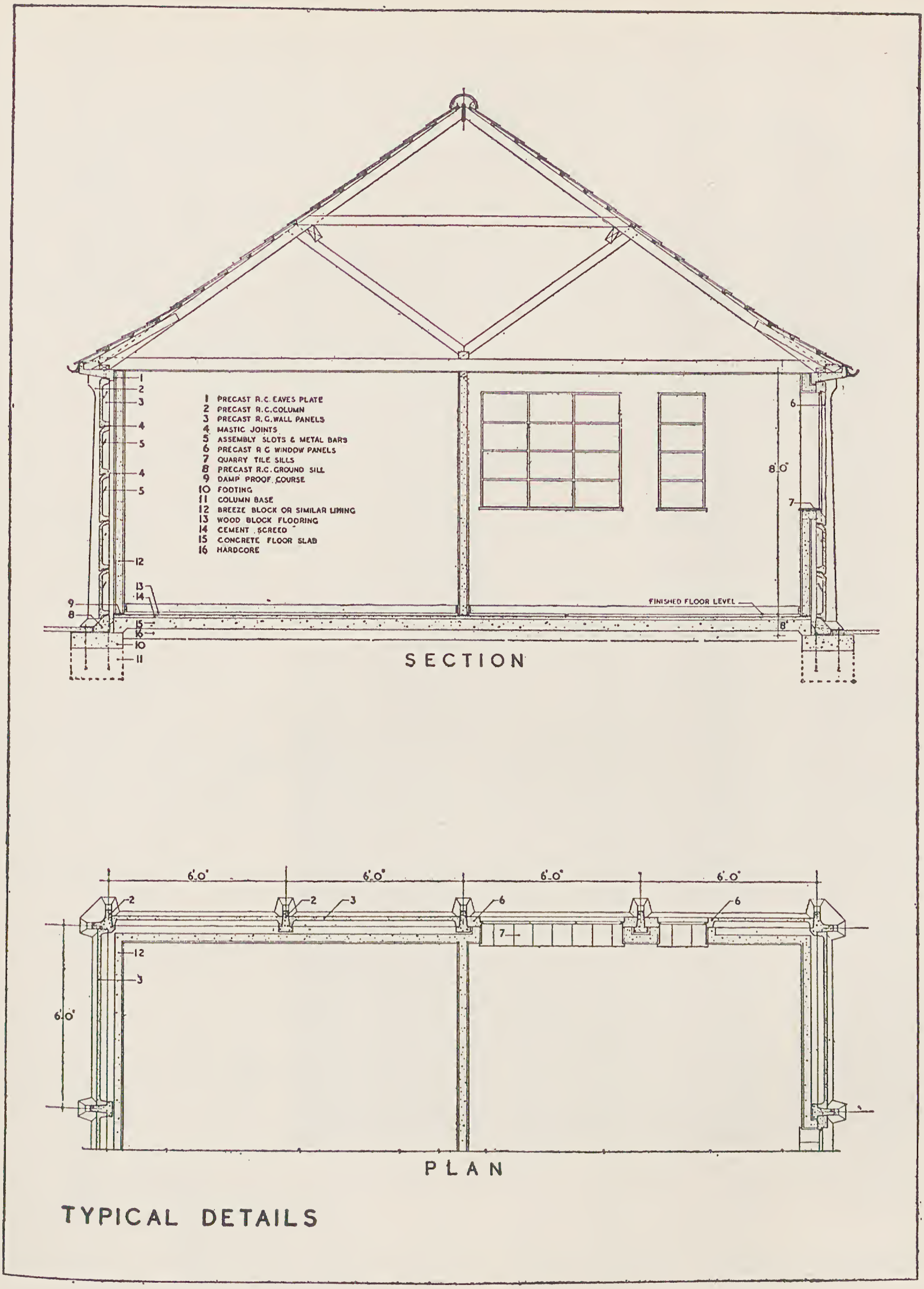


Fig. 136.—The B.C.C.F. system. Typical details.

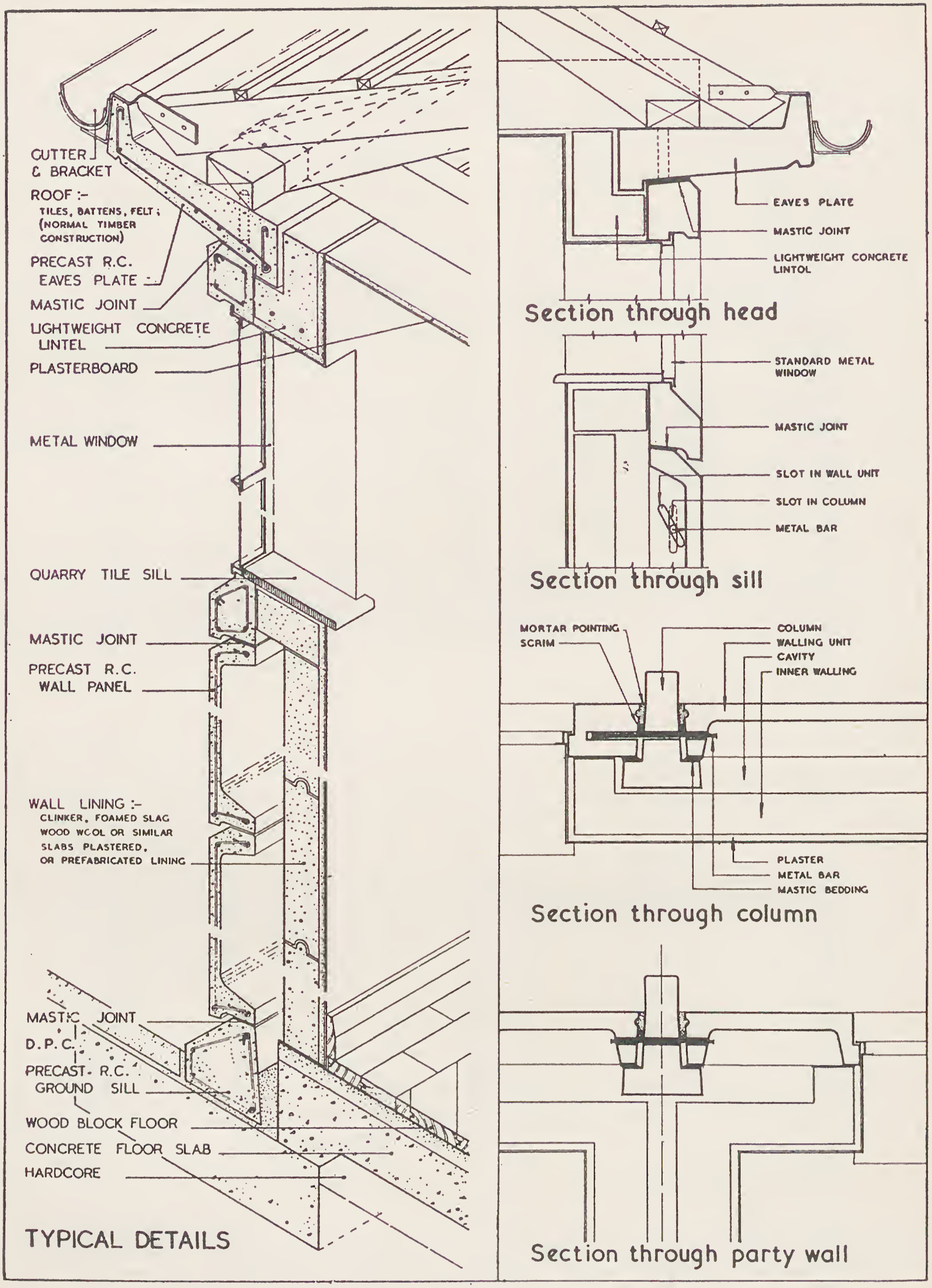


Fig. 137.—The B.C.C.F. system of pre-cast concrete bungalow construction. Typical details.

Built-in storage cupboards full height of room for brooms, crockery, etc.

Dresser with cupboards and drawers and linoleum top with serving-hatch to sideboard in living-room.

Built-in seat at window with lift-up flaps to provide storage.

Electric refrigerator unit with cupboards above and wire-mesh vegetable trays under.

Hot-water storage heater over sink as auxiliary supply.

Special built-in furniture to other rooms includes wardrobes and cupboards to bedrooms, sideboard and bookcase, and built-in coal-box in living-room.

There is a specially designed plumbing unit.

A built-in ladder gives access to the roof space.

Coal bunkers and a utility shed of pre-cast concrete units are provided outside.

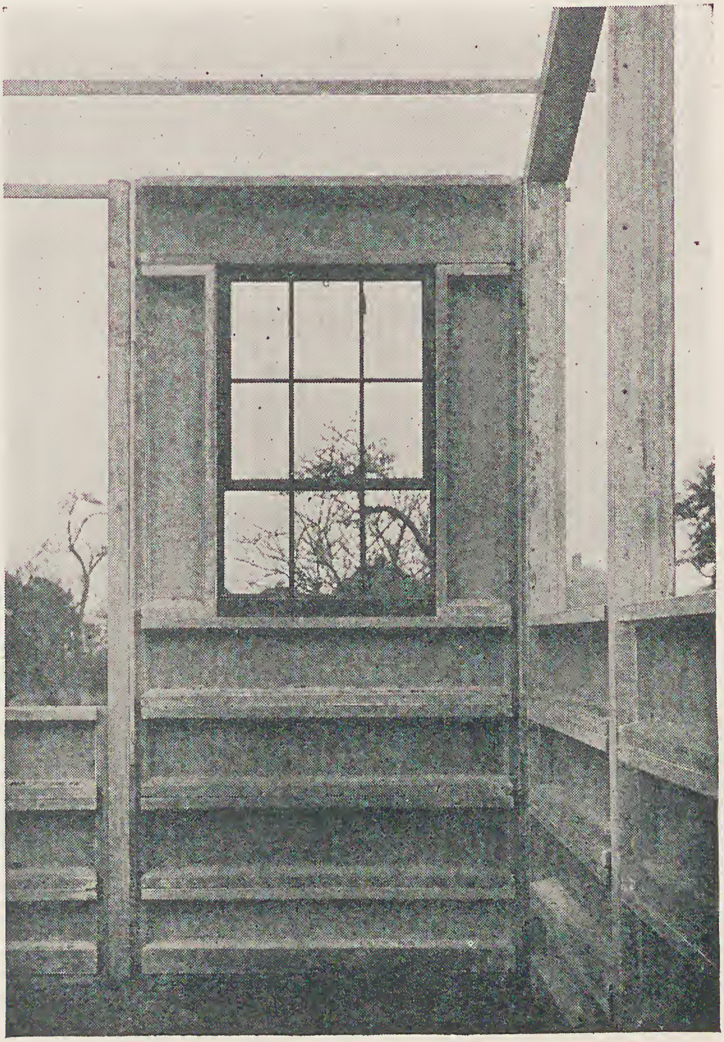


Fig. 138.—Post and panel wall in pre-cast reinforced concrete units.

STEEL-FRAMED CONSTRUCTION

Houses framed with steel sections and clad with steel sheets externally were prefabricated in factories to help to solve the acute housing problem just after the 1914–1918 war. According to a recent Government report, most of them are still in good condition and giving satisfaction to the occupants.

As with all framed structures, a great advantage is that as soon as the framework is erected the upper floor and roof can be fixed. This gives considerable protection from the weather, while the cladding and interior

work is fixed. This advantage applies to any framed building, whether prefabricated or site-built.

Recently designed systems for prefabricated steel houses have overcome many technical problems which in earlier systems were not satisfactorily dealt with. Methods of fabricating light steel frames on mass-production lines have been devised, with simplified fixings for the cladding and water-tight joints between sections. Instead of the standard rolled-steel sections, special light-gauge sections can now be formed, using sheet

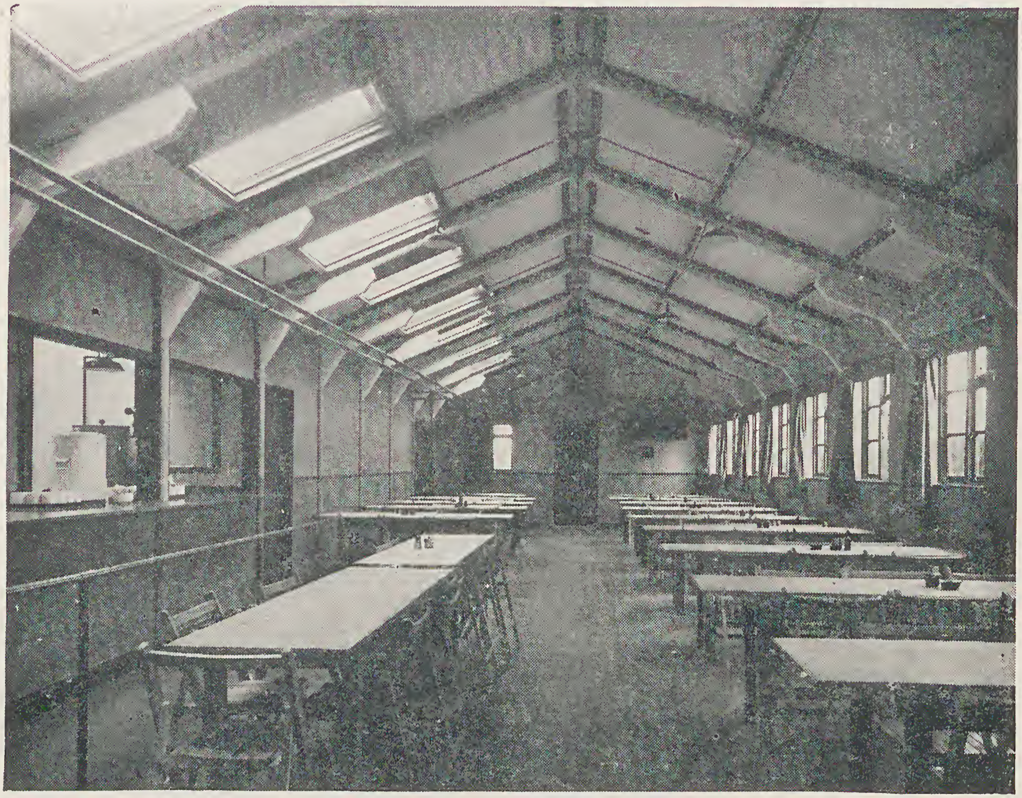


Fig. 139.—Canteen interior. Pre-cast concrete units, 30 feet 6 inches span.

metal and spot welding. Welding has supplanted riveting. The problem of rust-proofing has been tackled, and for the external steel cladding the method of paint harling has been proved efficient and of pleasant appearance.

The B.I.S.F. House.—This house has been designed by the British Iron and Steel Federation and large-scale production has been organised under the auspices of the Ministry of Health.

The B.I.S.F. house is of steel-framed construction and non-traditional cladding. Apart from the foundation and site slab, the party wall and the external rendering of the lower storey, the construction is almost

entirely dry, allowing the house to be occupied immediately after completion of the decorations. The structural steel framework consists of hot-rolled steel sections. The roof trusses are of tubular-steel sections with welded joints. The protection from corrosion adopted in this construction is based upon all recent research.

The structural steel frame is painted with red-lead paint at the works and, in addition, one coat of bitumen paint before delivery. Any damage during erection, and the bolts, should be touched up with bitumen paint.

The external steel wall sheeting is hot-dipped galvanised and, in addition, etched at works and dipped in an iron-oxide paint, so that on the

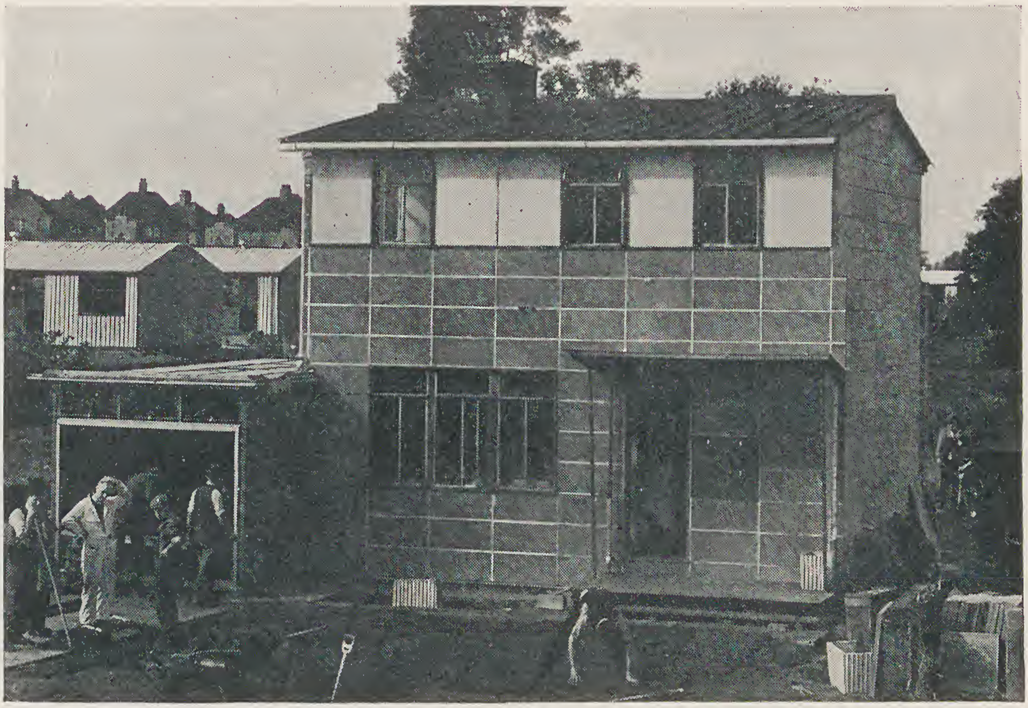


Fig. 140.—Prefabricated steel-framed house, Coventry. D. E. E. Gibson, City Architect.

face towards the external wall cavity the galvanising is itself protected, and on the external face two additional coats of colour in oil provide the decorative finish. The finish of the window sub-frames is hot-dipped galvanised, etched at the factory, and dipped one coat iron-oxide paint as a further protection and a base for the decorative paint.

After erection, all other exposed metal, whether internal or external, is painted two coats decorative paint. The thermal insulation provided is said to be superior to normal brick-and-timber construction.

Heating and domestic hot-water supply are provided by an Ideal open fire with a back boiler burning coke or coalite. The fire provides sufficient heat directly to the living-room and up to 15,000 B.T.U.s per hour to the

boiler. Provision is made in the heating system for radiators in the dining recess and two bedrooms. Valve controls on the radiators will enable preference to be given to the domestic hot-water supply at any time.

All pipes are so arranged as to be away from the external walls, and pipes in the loft are lagged. The cold-water supply cistern, besides being lagged, is placed immediately over the hot-water cylinder in the linen cupboard and adjacent to the flue.

Condensation in the roof is minimised by the provision of insulation at the loft floor level, and condensation inside the external walls is prevented

FRONT ELEVATION

Fig. 141.—Pair of B.I.S.F. houses. A prefabricated permanent system with steel framing.

by a ventilated cavity-wall construction and by provision of glass-fibre insulation behind the inner wall lining.

ALUMINIUM-ALLOY CONSTRUCTION

As aluminium alloys are light, easily fabricated, and corrosion-proof, they are widely used in aircraft construction. With the war-time experience of aircraft mass production in mind, firms in the aircraft industry formed the "Aircraft Industries Research Organisation on Housing" with the object of producing a light alloy prototype house—or, strictly speaking, a bungalow—suitable for mass production.

The A.I.R.O.H. house weighs less than 10 tons, and the prototype was fabricated in four sections—each 22 feet 6 inches × 7 feet 6 inches, and it was delivered by road from the works at Weston-super-Mare to the site at London, using 5-ton long wheel-base lorries. Each section as works produced is complete with plumbing, electric wiring, and all fittings.

A striking feature of this design is that no prepared foundation is necessary. It has built-in screw jacks which can be adjusted to suit the

site levels, and it can stand on concrete slabs or piers. Any foundation settlement can be taken up by adjusting the jacks. It is claimed that site erection need take no longer than 20 man-hours, including drainage and service connections.

Another striking feature is that the house is mobile. The four sections can be readily demounted and transported to another site.

The system evolved can be used for two-storey permanent houses.

The framework is of aluminium-alloy sections, with outer cladding and roofing of aluminium sheeting. Windows are also of aluminium. The floors are of 1-inch deal nailed to 3 × 2-inch joists, which are bolted to the floor chassis. Interior lining is of plaster-board and fibre-board.

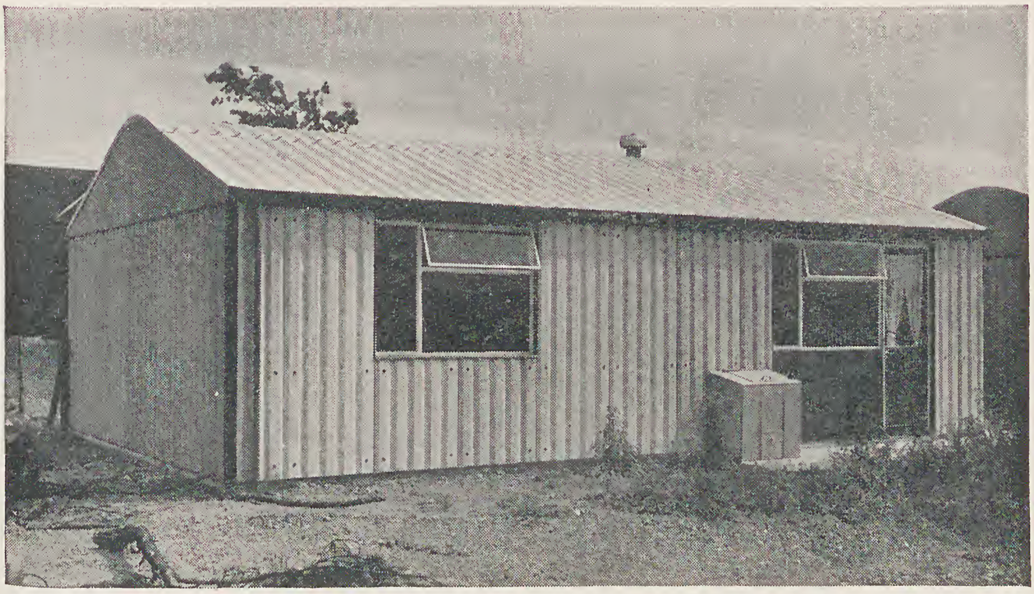


Fig. 142.—" Arcon " house with walls and roof of asbestos-cement.

Walls, roof, and floors are insulated. The exposed aluminium surfaces are painted, after being degreased. It is considered that the life of this type of house will be as long as that of any traditional type.

Cost of Prefabricated Buildings.—Prefabricated buildings of light construction designed for a short life have been produced at a much lower cost than the same size of building of traditional materials. But the systems described in the foregoing are of the highest standard in durability, thermal and sound insulation, and equipment. So far, these buildings (which are regarded as equal to, and in some respects superior to, traditional houses) have cost at least as much as traditional site-built brick-and-timber construction.

To reduce the cost, mass production on a large scale is necessary. At present the prefabricated house is emerging from the development

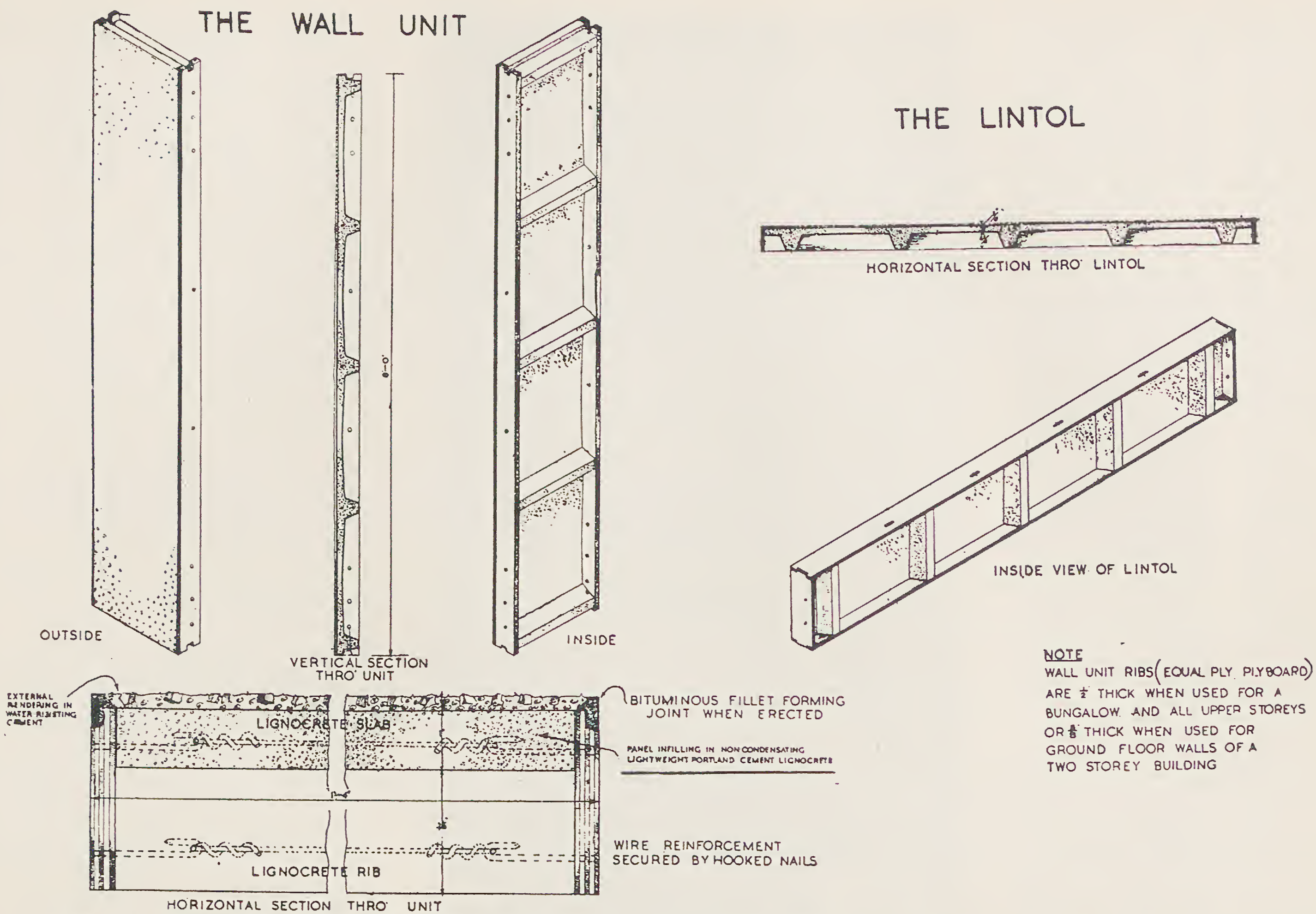


Fig. 143.—Details of the "Tarran" system. The units have ply-board ribs. The light-weight concrete wall slab is faced with water-resistant rendering.

stage. There are too many systems. To reduce costs, the best should be selected for large-scale mass production.

The Future of Prefabrication.—In the writer's view, this depends largely on cost. At present prefabricated houses have one striking advantage over traditional houses—speed of erection. In the period between the two great wars, the prefabricated houses then produced were only erected during the shortage of bricks and craftsmen skilled in the traditional trades. As soon as bricks and bricklayers became freely available, the prefabricated systems were dropped. It is true that there was then strong prejudice against prefabricated houses, but that prejudice still exists. If the cost can be reduced to bring it below that of traditional house construction, the prefabricated systems will continue to be used wherever houses are required without delay, and even though traditional materials and craftsmen may be available.

Prefabrication has been successfully applied to buildings for many purposes, including factories, offices, hostels, communal halls, hospitals, schools, and camps. For some of these purposes prefabricated buildings are preferable, even if there is no saving in cost. The hospitals and schools of to-day may be rendered obsolete in, say, twenty years' time by new methods of education and treatment requiring different layout plans. For such purposes, buildings which can be readily altered or removed are preferable to the heavy traditional type of building, which can only be altered or demolished at considerable cost and has very little salvage value.

CHAPTER 10

THE BUILDING INDUSTRY: ORGANISATION AND TRAINING

The building industry and its associated professions are now highly organised. In the past it was possible for men with little experience and no sound training to enter any of the trades or professions of building, but to-day it is very difficult, and in some cases quite impossible, for this to be done. As in any well-organised industry, the public are protected from quacks, standards of training, qualification, and conduct are laid down, and the interests of craftsmen, professional men, and employers are guarded by appropriate organisations.

It is now possible, and in most cases easy, for boys and youths, with talent and a genuine vocation for one of the building trades or professions, to obtain the best education and training to enable them to rise to good positions in the occupation which interests them most. Technical schools and training centres exist in all districts of Britain, where courses for all of the trades and many of the professions are available at very low cost.

In the professions of architecture and the various technical branches of construction, scholarships are available to enable youths with ability, but no private means, to obtain free education by taking full-time courses at recognised schools.

SOCIETIES AND INSTITUTIONS

These are mainly of four types:

1. Employers' institutions.
2. Professional institutions.
3. Trade unions and institutions existing to protect the interests of workers in building occupations.
4. Technical and craft institutions.

In some cases, membership is open to all persons genuinely occupied in the trades or professions for which the institution exists.

In others, membership is granted to those who pass approved examinations. Such membership usually carries designatory letters and is a recognised qualification.

National Federation of Building Trades Employers, 82 New Cavendish Street, London, W.1. This is the representative body for employers in the building industry. England and Wales is covered by

nine regions, in each of which there is a Regional Federation of Building Trades Employers. The National Federation performs a valuable service in representing the employers when such questions as wages agreements and forms of contract are negotiated, besides dealing with the numerous problems which are encountered in the business side of the industry.

National Federation of Building Trades Operatives, Federal House, Cedars Road, Clapham, London, S.W.4. This is the national representative body for all operative workers engaged in the building industry. It represents the operatives in negotiating wages and conditions of working, apprenticeship agreements, and on the many problems which arise in the development of the industry.

Association of Building Technicians, 5 Ashley Place, London, S.W.1. An association for all employed in a non-manual capacity in the building industry, including salaried architects and surveyors and technical assistants. The Association has done valuable work in raising working conditions and in securing fair rates of remuneration for its members. But while performing the functions of a trade union, it also takes a lively interest in modern technical problems, on which it has published reports and leaflets.

The Institute of Builders, 48 Bedford Square, London, W.C.1. There are four classes of membership, *viz.* : Fellows, Members, Associates, and Licentiates. The last three are obtained by passing examinations, conferring the right to the designatory letters M.I.O.B., A.I.O.B., and L.I.O.B. respectively. There are also Probationer and Student classes, open to persons with suitable qualifications.

The usual preparation for the examination for L.I.O.B. is the National Certificate Course. On obtaining the Higher National Certificate very little further study should be necessary to enable the Licentiateship examination to be taken. After taking the Licentiateship, a further year's study is necessary before taking the examination for the Associateship. Actual experience in building organisation is required before membership is granted. The examinations set a high standard, but the qualifications mentioned are widely recognised, and are of great value in seeking positions of responsibility in the industry.

Architects' Institutions.—The description "Architect" can only be used by those who have been admitted to the Register of Architects kept by the Architects' Registration Council of the United Kingdom, 68 Portland Place, London, W.1. This body depends for its authority on the Architects' Registration Acts, 1931 to 1938. The Council lays down educational standards and a code of professional conduct for architects.

Registration is granted to those who pass approved examinations. The examinations of the Royal Institute of British Architects are at present the only approved examinations for this purpose.

The Royal Institute of British Architects, 66 Portland Place, London, W.1, issues a leaflet on architectural training and qualifications.

Specialist Institutions.—Amongst the institutions to which admission is by examination are :

The Institution of Structural Engineers, 11 Upper Belgrave Street, London, S.W.1.

The Royal Institution of Chartered Surveyors, 12 Great George Street, London, S.W.1.

The Royal Sanitary Institute, Buckingham Palace Road, London, S.W.1.

The Institution of Civil Engineers, Great George Street, London, S.W.1.

The Incorporated Association of Architects and Surveyors, 75 Eaton Place, London, S.W.1.

APPRENTICESHIP

The various official schemes connected with apprenticeship and training for the building industry may be divided into two main parts : schemes for normal apprenticeship ; special schemes to meet the shortage of skilled craftsmen following the 1939–1945 war.

The National Apprenticeship Scheme.—The National Joint Council for the Building Industry has appointed a standing committee—the National Joint Apprenticeship Board (in Scotland, the Scottish National Joint Apprenticeship Board)—to administer the scheme of apprenticeship.

Apprenticeship to any of the " arts, crafts, and trades forming part of, involved in, or associated with the construction of buildings and public works " is normally for a period of five years, beginning on the boy's fifteenth birthday and ending on his twentieth birthday, or beginning and ending a year later.

If the boy has satisfactorily completed a three-years' course in an approved junior technical school, the apprenticeship may be reduced to four years, and in the case of a boy who has satisfactorily completed a whole-time Senior Day Course it may be reduced to three years. A probationary period of six months is provided for.

Provision is made for technical education during the apprenticeship period. The boy must attend evening classes twice weekly and also day classes for two half-days or one whole day weekly, for which the employer must allow the boy time off. Fees are paid by the employer.

There are four parties to the standard deed of apprenticeship : the Employer, the Guardian, the Apprentice, and a Representative—the last being an employer selected by the Local or Regional Joint Apprenticeship Committee.

The scheme is administered by Local and Regional Joint Apprenticeship Committees, on which both employers and operatives are represented. Provision is made for arbitration and appeals in matters of dispute.

The Building Apprenticeship and Training Council.—This body represents : The building trades and civil engineering employers, the

operatives in those trades, the professional institutions connected therewith, the educational authorities, and the appropriate Government departments. The B.A.T.C. was formed following the recommendations contained in the Government White Paper, Cmd. 6428, on "Training for the Building Industry." Its objects are :

(*a*) The comprehensive review of existing apprenticeship schemes.

(*b*) The definition of minimum standards to which approved schemes should conform.

(*c*) The maintenance of a register of apprentices in training under approved schemes and the issue of certificates on completion of training.

(*d*) The promotion of publicity designed to stimulate interest in building as a career.

(*e*) Practical methods of encouraging employers and apprentices to participate in approved schemes.

To secure these objects the B.A.T.C. make recommendations to the National Joint Apprenticeship Board.

Registration of Apprentices.—This is a very important part of the National Apprenticeship Scheme. When boys are apprenticed under the scheme they are registered by the J.A.C., which obtains regular reports regarding the progress of the apprentice. Boys receive a Registration Card on commencing apprenticeship, and on satisfactory completion of training a Certificate of Completion of Training. This Certificate is obviously of great value as a proof of proper training and qualification in their craft.

Adult Training.—The schemes for the training of adults and disabled persons to meet the special conditions following the war has been arranged by the Government in collaboration with the building industry. Particulars can be obtained from any office of the Ministry of Labour and National Service.

Technical Education.—Courses for apprentices, craftsmen, and other students of building construction are held in all technical schools. They are of three types :

1. Junior or Preparatory Courses, intended for those whose education falls short of the standard required on entry to 2 or 3, below. Elementary drawing, science, and calculations are the chief subjects.

2. Building Craft Courses, designed to give full training in the individual crafts. There are courses for bricklayers, carpenters, plasterers, and all the other crafts. Students are prepared for the examinations of the City and Guilds of London Institute.

3. General Building Courses, designed to give a comprehensive education covering practically the whole field of building. In the later stages specialised training is given to prepare the student for specific branches or departments of the industry. On passing the final examinations students are awarded the National Certificate in Building.

The National Certificates.—Apprentices, craftsmen, and other students

of building who wish to obtain a position of responsibility in the industry should take the approved general building course (available at the larger technical schools), so that they can obtain one of the National Certificates. These are:

1. The Ordinary National Certificate, obtained by satisfactorily completing an approved three-year course of evening classes.

2. The Higher National Certificate, obtained by taking a further two-year approved course in advanced subjects, usually of a specialised nature.

These certificates are now widely recognised as sound qualifications for the higher positions in the industry.

At certain schools, notably the School of Building at Brixton, London, full-time day courses are available.

The National Certificate course is a good preparation for the examinations of the Institute of Builders, membership of which carries designatory letters (see page 199).

EXECUTIVE ORGANISATION

The success of a building operation depends more on the proper organisation not only of the work on the job but of the building contractor's office and work than even on a sound knowledge of building construction. Indeed, the latter without the former is useless if it is desired to conduct building operations as a financial proposition. Even in those rare instances where craftsmanship is the main interest, good organisation cannot be anything but a help to that end also.

It is an indisputable fact that where sound organisation, including a reliable and easily referred to system of book-keeping, is the backbone of a builder's business, not only the financial success but also the workmanship is the more sound and reliable. Yet it is an equally indisputable fact that perhaps in no other industry, except possibly the clay-working industry, is the idea held so firmly that what served in the past ought to be good enough for the present. To hold any such belief is to fall behind one's competitors in the modern rush for progress.

Good organisation applies not only to the organisation of the contractor's office, but to the organisation of the job also; and whilst it is unlikely that if the head office be well organised the jobs will be allowed to be carried on in a slip-shod way, yet such conditions are not unknown; and even so there are degrees in the organisation of the job which can exist and be developed apart from the organisation of the office.

That good organisation in both is the only high-road to financial success ought to be a sufficiently convincing argument to any contractor who enters upon the building business with that end in view. It may be that a builder in a small way will think that good organisation is beyond his scope; but the truth is that it is even more vital to him than to the larger concerns, as loss to him, due to lack of organisation, may well mean

losing all, whereas in larger offices loss on one job may be made good on another.

The organisation of all the various energies that go towards the erection of a building is one which has grown up rather out of custom than from any definite plan. Originally the architect was what his name means, the chief builder, and, as has been said, there are indications of a tendency towards a return to this proper condition in so far as a partnership between the builder and the architect is now becoming recognised as the best method of satisfactorily conducting extensive building operations.

The start of operations ending in the erection and completion of a building is the desire on the part of someone or body of people that a building should be erected. This may seem somewhat obvious, but it is a point which has been frequently overlooked, not only by the masters and operatives in their controversies over wages, but also by the architect in his natural desire to give expression in material to his artistic instincts. If the operatives and masters when fighting each other over how much or how little should be paid in wages, and if the architect when designing the building, were to reflect that it is in the end the building owner's money which is being spent, and that is making the efforts of any one of these possible, such reflection would result in the undeniable conclusion, that whoever's interests may be worthy of consideration, those of the building owner are the first.

The first step actually taken, in fact, before any of the other energies may be employed on building operations of any extent, is for the building owner to consult an architect. Much time and study is given to the requirements of the building owner, and the embodiment of these in a suitable plan upon a site which has been decided upon as satisfactory. A specification is prepared from the drawings when they have been approved by the building owner, and a bill of quantities is prepared from these. All this work—and sometimes it is very considerable and may be considerably increased where the site requires surveying and levelling—has to be undertaken before it is possible that any of the work of the various people, who follow subsequently, may be employed.

Tendering.—A builder will soon discover that the main source of his work will be by recommendation, and fortunate is the builder who, by the satisfaction which he gives, establishes a connection by which he is able to maintain a constant flow of contracts for which he is invited to tender. Contractors there are who, by reason of the reputation which their work has established, have surrounded themselves with a number of architects so well satisfied in their integrity and workmanship as to place orders with them without the introduction of competitive estimates from other contractors. This should be the aim of every contractor—to arrive at such a satisfactory state, but unfortunately it is not. An invitation may be received in writing to submit a tender in competition, or the job may be advertised in the Press, as is invariably the case when the work is for a public body. In some instances, especially in repair

jobs, an agreement is arrived at where the contractor is asked to undertake work without a tender, charging the actual time and materials cost, together with an agreed percentage for profit. The reason why such a method applies to repair jobs is that until the state of the building is laid bare by pulling down, it is often impossible to know the extent of the work required. For such work as this an architect will generally employ contractors whom he knows, and certain contractors determine to specialise in repair work.

The forms which the invitation to tender is likely to take will state whether the competition is limited or open, and are as given under :

Invitation to Tender—Limited Competition

Address of Architect..............................

Date ....

Erection of .... at ....

For ....

SIR (or GENTLEMEN),—

You are invited to tender for the above work.

Bills of Quantities will be supplied, but their accuracy is not guaranteed.

The plans and specification may be seen, and copies of Bills of Quantities obtained, at my office at the above address any day between .... a.m. and .... p.m.

The lowest, or any, tender will not necessarily be accepted.

I should be obliged if you would inform me, as early as possible, if you are able and willing to send in a tender ; on receipt of which information, the necessary documents will be forwarded to you.

Yours faithfully,

....

(Signature of Architect.)

To .... (name of Contractor addressed).

Alternative Form

Or the following form may be used, headed as last :

SIR (or GENTLEMEN), –

Erection of ....

At ....

For ....

You are invited, with others, to tender for the above works, and, for that purpose, I enclose a copy of the Bills of Quantities.

The plans and specification may be seen at my office at the above address any weekday between .... a.m. and .... p.m.

Tenders are to be delivered to my office, as above, not later than .... a.m........... (date) in the enclosed envelope or other similarly endorsed.*

The lowest, or any, tender will not necessarily be accepted.

If you are unable or unwilling to send in a tender, I should be obliged by your returning the enclosed copy of Bills of Quantities at your earliest convenience.

Yours faithfully,

....

(Signature of Architect.)

* Endorsement on enclosed envelope—TENDER for the erection of .... at .... to be delivered not later than 10 a.m. on ....(date.)

Advertisement for Tenders—in Open Competition

To Contractors, Builders, and Others.

The undersigned is (or are) prepared to receive, on behalf of .... (the Building Owner), tenders for the erection of .... at .... according to the plans and specification which are at his office and are to be seen on any weekday between .... a.m. and .... p.m.

A copy of the Bills of Quantities and of the Form of Tender may be obtained on payment of a fee of £.........., which will be returned to anyone who sends in a bona fide tender for the work.

Tenders are to be addressed to the undersigned at his office at above address, under cover, and endorsed " Tender for .... at..............................," and must be delivered not later than .... a.m. (or p.m.) on .... (date).

The lowest, or any, tender will not necessarily be accepted.

Dated ....

....
(Name and address of Architect.)

Deposit.—Generally a deposit will be required before the plans and specification are delivered to the contractor as a testimony of his bona fides. This deposit is returnable on the submission of a tender, and the contractor should see that it is returned to him. But even before making the deposit and consenting to tender, the contractor is advised to ascertain if the quantities will form part of the contract or not, and he is further recommended not to tender for any job over two thousand pounds for which quantities are not supplied. Also before preparing the tender the contractor should ascertain what form of contract he will be required to sign in the event of his tender being accepted.

Estimating.—On agreeing to give an estimate the contractor is handed a copy of the plans and an unpriced form of quantities. He will also receive a copy of the specification, though this is not so necessary where there are quantities, as the one is mostly embodied in the other. He should also obtain at the first interview a form of contract which has been referred to above. Before setting his estimator to work upon the figures the contractor should visit the site of the proposed building in company with his works manager and a general foreman. The purpose of this visit of inspection is to obtain information as to, firstly, the accessibility, upon which the cost of carting will to a great extent depend, and in the event of any demolition to ascertain the exact extent of this. He will at the same time make notes as to any underpinning and shoring that may be required, and the most economical way that this may be executed in conformity with sound construction. He will then compute the time required to complete the work and estimate before taking any further steps whether this is economically possible within the time required by the building owner, of which time, if it is not contained in the documents, he should have obtained information when replying to the invitation to tender. He will also require to form a provisional estimate of the extent of the staff.

The estimator, having priced the bills of quantities, should add for overhead charges and on-costs. These last include hoardings, clearing the site, erecting hoardings, and making roads if any, wear and tear of plant, insurances, etc., and a percentage for profit should be added.

There is a clause in the invitation to tender stating that "the lowest or any tender will not necessarily be accepted," in which event the arrangement would be of little value, as though it is reasonable to expect that a lowest tender should be accepted, this is not always the case, nor is there any obligation, even if the clause above referred to is not contained in the invitation to tender, for the building owner through his architect to accept the lowest or any other tender, as an invitation to tender for a proposed building is not in any way a contract that a building shall be built.

The estimate will be required to be submitted on a certain date, and the contractor or his representative should experience no difficulty in being present at the opening. It would only be a very inexperienced architect who wrote accepting any tender for the proposed work on his own account. The building owner should, if possible, be present at the openings of the tenders, and the formal acceptance of a contractor's estimate should state clearly, though supplied by the architect, that he is accepting on behalf of the building owner. Similarly the contract when drawn up is between the building owner and the contractor. The architect acts as the agent of the building owner, and whilst his authority is clearly defined, and the building owner is bound by all his acts (unless of course these constitute fraud outside the scope of his authority), the contract between the architect and the building owner, if it does not actually state it, implies the agency of the architect on behalf of the building owner.

The Contract.—The form of contract usually adopted is that issued by the Royal Institute of British Architects with the sanction of the National Federation of Building Trades Employers and the Institute of Builders. There are two forms: one for use where quantities form part of the contract and another for use where quantities are not part of the contract. The former is reprinted in full in Chapter 12.

A form of contract for sub-contracts is issued by the National Federation of Building Trades Employers, and is reprinted in Chapter 12.

Certificates.—Under the terms of the standard forms of contract, payment is made by the proprietor to the contractor on the production of certificates issued by the architect. Copies of the Architect's Progress Certificates; the Architect's Certificate, the form published by the Royal Institute of British Architects; the Certificate of Completion; and the Final Certificate are given under.

Architect's Progress Certificate

No. ....
.... 19......
To ....
of ....
on a/c of ....
at ....
belonging to ....
previously certified } £ : :
now certified £ : :

Total £ : :

No. ....
To ....19.....
.................HEREBY CERTIFY that the sum of
....
is due to .... of ....
on account of ....
£ : : previously certified ....
now certified. ....Architect.
£ Total.
Received from .... the above sum of
£..............
.... (Signature of Contractor.)

Architect's Certificate

(The Form published by the Royal Institute of British Architects.)

Architect's address ....
....
............19........
Certificate No. ....
Previous Instalments £......
Present Instalment £......
Total to date £......
Certificate in favour of........
....
on a/c of Works at ....
....
under the terms of the Contract
therein, dated ....19....
Amount £
Addressed to ....

Architect's address ....
Certificate No........... ...... 19.....
Previous Instalments £................
Present Instalment £................
Total to date £................
.... HEREBY CERTIFY that the sum of
....
is due to ....
of ....
on account of Works at ....
under the terms of the Contract therein, dated ....
19......
£
....
Architect.
To ....
....
Contractor's Receipt.
.... 19........
Received from .... Stamp ......
the sum of £ ....
in payment of Certificate No. .... dated ....19....
£

Certificate of Completion

Works at..

For...................................

No..............................

I HEREBY CERTIFY that subject to the repair of defects and omissions (if any) found during the period of maintenance, the Contractors, Messrs.............................. have now completed the above Works to my satisfaction.

The state of accounts is as follows :

Amount of Contract		£ : :
Extra Works		£ : :
Total		£ : :
Less : Omissions on the Contract		£ : :
Total due.		£ : :
Deduct :		
Retention money	£ : :	
Total previously certified . .	£ : :	
Net amount now payable		£ : :

....

I hereby certify that the said net amount of £ : : is now payable to the said Contractors.

....
(Signature of Architect or Engineer.)

Date......................

Final Certificate

Works at ....

For ....

I hereby certify that the terms of the Contract for the above Works dated the........... day of .... have been fully observed and performed by the Contractors, M...... .... and that they are now entitled to be paid the sum of £ : : , being the amount of the balance of the retention money under the Contract dated ....

....
(Signature of Architect or Engineer.)

Date........................

Stamping Contract.—A contract must be stamped under The Stamps Act and the stamp duty is 6*d*. for ordinary contracts between private individuals, but contracts with public bodies will be under their seal, in which case the stamp duty is 10*s*.

THE CONTRACTOR'S STAFF

The office staff of a large contracting business is a considerable one, and, in addition to this, there is the permanent staff of outside men, it being obvious that a contractor cannot employ new foremen every time he starts a new job.

In the Office there is, of course, the contractor himself, as the head of the concern, or in a limited company, directors, one or all of whom may be working partners. If there are several members it is probable that they will each take the supervision of a separate department.

Next, there should be a general manager, with possibly an assistant manager and secretaries.

The main departments under the general manager are the office staff for routine duties—the estimating department, the purchasing department, stores, and the book-keepers. For outside work, there may also be a surveyor's department—works superintendent and foremen (general and trade). The number of employees under each department head will naturally depend upon the yearly turnover. But whatever department may be cut it is an unwise economy to try to save money in the book-keeping department.

The General Manager.—It will be obvious that a general manager of a building business must have a thoroughly practical knowledge of the trade whatever other qualifications he may possess. It is sometimes thought that, his functions being mainly administrative, this is not required, but nothing could be further from the truth. This is readily understood when it is brought to mind that all administration, however intricate it may be, is, after all, concerned with the operations of building, and with no other.

Whilst the general manager must supervise the work of all the other heads of departments, that department with which he will be in most direct touch will necessarily be the general business office. The most important correspondence will require his personal attention, and all other correspondence should be under his supervision. It will also fall to his lot to interview the building owner, and at such meetings as when quantities, extras, payment of accounts, or legal matters arising out of any contract are under discussion, it will be essential that he should be present to safeguard the interests of the contractor. The introduction of new business also is often considered part of the functions of the general manager. Indeed it is difficult to see which of all the thousand and one matters in the work of a building contractor does not at some time or other fall upon the shoulders of the general manager. He must know how to do everything, short of placing a wreath upon his own grave.

The Works Superintendent.—In any contractor's office where jobs of any size are undertaken, a works superintendent is essential. A good definition of a works superintendent is that he is the organiser-in-chief of the builder's outside work. He also supervises all the trades, the yard works, stores department, and plant, and serves as a link between

the staff working on the jobs and the staff in the head office. His qualifications must therefore be practical, theoretical, and administrative, an exceptional combination creating a very valuable personality. The assistance of the works superintendent is essential in the preparation of the progress schedule referred to above; and in connection with specialist sub-contractors and special material nominated in the specification, it will be the works superintendent's duty to interview the architect, submitting samples and obtaining his approval. Further, the foremen of the different jobs may be excellent men for their positions, and exercise the necessary vision in ordering materials before they are wanted, but they will be helpless to push the job forward if the same expedition is not practised in the head office. In the same way, any dilatoriness on the part of sub-contractors, especially nominated sub-contractors who are often apt to be more awkward than any others, can seriously hold back the progress of a job, and in this the works superintendent, working in accordance with the progress schedule, will be instrumental in keeping the progress of the jobs up to time.

It is also part of the works superintendent's duty to see that the weekly wage totals are in the head office by Wednesday morning and a supervision of insurance cards may also be required of him.

In the Home Office Regulations relating to safety in scaffolding, cranes, etc., certain reports are required concerning tests of this plant. It will be required of the works superintendent that he should be present when the tests are made, and to see that the required reports are forwarded.

The works superintendent should have the appointment of all foremen and in constantly visiting the jobs he will always have an eye open for any trade foreman who shows an aptitude and whom he will mentally mark for advancement when opportunity occurs.

The Estimator.—Except in the very largest offices a builder's *Estimator* is generally the *Buyer* also, but with the very biggest contractors the buyer is the chief clerk in the general office department.

The functions of a buyer require considerable knowledge of the trend of affairs in the building trade, as the buyer, working in conjunction with the stores department, buys not only materials for the particular jobs in hand but may be instrumental in saving a considerable amount of money by buying for the future at times when materials come into the market cheaply.

Surveyor.—It will only be in the very largest businesses that a whole-time surveyor will be appointed, though there should be a drawing office in which the shop details and the full-size details supplied by the architect may be prepared and re-drawn when required.

The laying out of the foundations on the site and the checking of the levels shown on the plan will fall to the surveyor.

Storekeeper.—The office of the storekeeper is self-explanatory and he will be required to keep a check on all incoming and outgoing materials.

Transport.—Perhaps in no department of a builder's business is organisation more necessary than in the transport section. In fact large commercial firms have a *Transport Superintendent*, and though this is usually a highly paid appointment the organisation which he introduces has been found a very economical proposition. The most careful data and statistics of running costs, petrol consumption, road repairs, etc., are collected and very carefully checked, with the result that it has been found that there is no longer any duplication in the expenditure of these matters, and waste is of course eliminated.

In these matters the contractor's work will benefit considerably by the appointment of a transport manager. But even more in the contractor's particular business benefit is to be gained from a proper supervision which ensures the reduction to a minimum of running light, that is, taking a load one way and running back empty.

Also the transport manager, by drawing up a proper time-table, in conjunction with the works foreman or the general foreman, will save very considerable time previously wasted by ensuring that loads arrive at the jobs at times when gangs are free to unload.

The transport manager will find it essential to ensure the actual delivery and acceptance of the materials on the jobs to which they are consigned, and in this perhaps the ideal checking system has yet to be found, as it is not unknown that considerable supplies of materials consigned to a large building estate were signed for at one entrance, carted through the estate, and out at another entrance, and deposited and used on another estate.

The General Foreman.—Contrary to the customary belief, perhaps the most responsible position in the contractor's business family, next to the general manager, is that of the general foreman on the job.

The position is at the best of times a difficult one. The foreman is in the first place a practical man, and to a practical man who has worked at his trade anything but the best workmanship must be very distasteful. Yet there constantly arise occasions when speed is essential, and, owing mainly to underpricing of keen competition, it is not always easy to ensure either workmanship or materials which under happier conditions would be preferred. Yet the general foreman will be expected by the contractor to show a good profit on his expenditure in wages, time, and materials.

On the general foreman's shoulders, too, will fall with heaviest incedence the dealings with those often most troublesome people—the sub-contractors. Probably hardly a single large building contract has ever been carried out without one or other or all the sub-contractors making as much trouble as a temperamental leading lady who fancies the whole play to have been written for her benefit alone.

Another very important duty of the general foreman will be the ordering of materials ahead of the time when they will be required. For though the works superintendent is the official actually responsible in the office for this work, yet for this and much else besides he will look to the general foreman on the job for his information.

Further, though possibly the foreman may not be legally responsible for accidents arising on a job if it can be proved that he followed the plans and specification, yet his position will be rendered extremely difficult in some instances, as for example, should collapse occur whilst shoring or underpinning works are in progress.

A general foreman will have been, or should have been, chosen for his position mainly on account of his knowledge of men and his ability to keep things moving sweetly. "Sweetly" is one side, and a necessary side, of the matter, but "moving" is even more important from the contractor's point of view. To this end, the foreman will be much assisted by his trade foremen, and in his choice of individuals for these positions will he display his main qualifications. For it is only by very close team work on a job between the trade foremen and the general foreman that the operatives in the various trades can be kept moving, one assisting and making way for the other without the necessity for constant dismissing and re-employing of men.

The general foreman, having been trained to a particular trade, may have preferences which will make him more at home on certain classes of jobs than others. Some think that masons make the best foremen, but as the carpenter is generally the first man on the job and the last to leave, and his work is required in the assistance of all the other trades, his practical training is likely to be the more extensive. However, it is not so much on account of such qualifications that a foreman is chosen, as for his tactfulness in dealing with the many difficult situations that are almost bound to arise in the course of any building work.

For instance, a man may be very successful in handling other workmen, but he may experience difficulty in submitting himself to authority. Many architects will require careful handling if the job is to run smoothly, and to some the presence of the architect's representative—the clerk of works—on the job all the time may become irksome. Friction here will tend towards reactions; and as a contractor's business is built up more on recommendation than from anything else, the maintenance of friendly relationships is of the first importance. In this matter it is also worth noting that all instructions concerning the work should be given to the general foreman, when on the job, not only by the contractor, but by the architect also when the contractor is not present. The foreman has the right, and in many instances it is his duty to request that any instructions so given should be confirmed in writing. Especially is this the case where any extra work is involved ; as in most contracts there is a clause that extra work will not be paid for unless a written order can be produced authorising them.

Though the contractor or, where there is one, the works superintendent will throughout the contract require to discuss the progress of the operations, the actual conduct of these operations employment of men, and ordering of materials, should be left to the general foreman. By ordering, however, is not meant purchasing, which must be done through

the office. The foreman should remember that as his is not the only job he should send in his requisitions ahead of time when the materials will be needed. In fact, the foreman's job consists to a large extent in his foreseeing the work ; otherwise a very considerable amount of time may easily be wasted. Profits on contracts are, where there is keen competition in estimating, largely a matter of savings effected on the works. Consequently, the foreman will be well advised to study the plans and specification, copies of which he will, of course, be supplied with, with a view to making a list of matters to be discussed with the contractor at his next visit.

This brings us to the vexed question of book-keeping on the job, and in spite of what may be said in this matter with a view to modernising the organisation of building operations the practical man will agree that the less book-keeping that is done on the job, the better.

The foreman is primarily an outside man. The trades with which he has to be conversant are : the excavator and concreter ; bricklayer ; stonemason ; pavior ; slater and tiler ; carpenter ; joiner ; plumber ; glazier ; painter and paperhanger ; and lighting and heating engineers. The proper supervision of this large variety of operations will keep him and his assistants sufficiently occupied without duplicating the work of book-keeping, which is essentially an office job.

The foreman's requirements in this respect will be satisfied if the following books are provided : time books ; weekly pay sheet ; time schedules, showing progress which is required to be made in each trade ; materials sheets ; day work sheets ; and extras or variations sheets.

He should also have a supply of the firm's addressed stationery, his correspondence being mainly confined to the contractor's office, and all his correspondence and sheets should be duplicated, the originals being sent to the office together with all delivery notes for goods received on the job. The extras sheets will require to be produced at the time when the quantity surveyor is checking the extras by measurement, and it will save time and possibly controversy if the foreman gets the clerk of the works to sign these sheets as being correct.

Where haulage is let, there should also be a haulage time sheet, on which is entered the date ; name of haulier ; number of loads ; materials ; details of journey and cost. These should also be sent in weekly to the office, to be entered in the transport book. Where the contractor does his own cartage the driver's time is entered in the ordinary time sheet. The foreman will, of course, assure himself that the goods for which he signs are actually delivered on the job.

Manifold books for any additional reports or drawings of difficulties which may arise should complete the stationery requirements of the foreman.

There should also be in the foreman's possession a certain amount of petty cash, for " subbing " workmen, and outside expenses, details of which will appear in the time sheet.

CHAPTER 11

THE BUILDING INDUSTRY: BOOK-KEEPING

THE necessity for good organisation of the Office, backing up the good organisation of the Works side of the business, has been stressed elsewhere in this book, and to repeat this and to add that a Builder cannot afford to depend in this matter entirely on Works or Trade Foremen, who invariably do not profess to have any clerical aptitude, can do no harm.

The activities of the Office Staff precede the " obtaining " of the Contract, on which later the Works Staff will operate ; once the Contract is fixed, there are many duties resulting in clerical work covering :

- Correspondence with the Local Surveyor, etc.
- Insurance against Fire, Accidents to Workmen, etc.
- Arrangements for tests of plant, ladders, etc.
- Choice of Foremen.
- Production of a board giving the Contractor's name and address, and any other details, to be hung in a prominent position on the job throughout operations, and acting as an advertisement.
- Entry of the main points of the Contract into the " Contract Accounts Book," showing Time allowed for job, any Time Limitations, and Penalty, and all Arrangements arrived at, affecting the performance of the Contract.
- Arrangements with Haulage Contractors and Sub-Contractors, if parts of the job are to be " let."
- Arrangements for the conveyance of plant, hoardings, scaffolding, etc., to the site of the job.

The work of recording all details of transactions which will eventually lead to " payment of account " of course fall to the Book-keeper, and the very fact that the Accountant makes himself instrumental in keeping a sound system of Book-keeping and Costing cannot fail to reflect throughout all the branches and trades embodied in Contracts, and so to avoid muddle and even chaos, though work may at the one time be progressing at a number of separate points.

Every business deal resolves itself into what the book-keeper will translate into " the giving of value " set against " the receipt of value," and Double Entry Book-keeping will be his means of efficiently recording facts.

Everything that comes in, and everything that goes out, moneys, or goods of monetary value, must, by the systems operating outside the office, be brought to the notice of the book-keeper, who will put these items through his records, later either paying some person or firm for value received, or receiving cash in lieu of work completed.

It will be understood that a Builder does not make a " sale " in the ordinary sense of the word ; that is to say, his order does not cover some already manufactured item, which can immediately be passed to the customer. He supplies certain materials, constructs to the customer's requirements, with the aid of labour and supervision which he supplies, and on to which he will of course add the amount of profit he requires to make on the transaction.

This book, dealing as it does essentially with construction, cannot presume to treat book-keeping fully, and therefore submits only a brief survey of the records kept behind the scene of the actual execution of building.

The Accountant will be able to draw conclusions from contact with the business, exactly the number of books he must keep in order to record satisfactorily all the transactions of the firm to which he is attached, but the following will probably be the requirements :

The Contracts Journal, which is more or less a Register of Jobs undertaken, which will later be chargeable to some client. It is not necessary to write out the Specification in full (that will be filed somewhere in the office for quick reference), but just to give enough essential detail in outline, for transference to a ledger account. A separate page should be used for each Contract ; and each Contract will have a number which will show in every Memo., Invoice, or Letter respecting that particular job. The Contracts Journal will receive frequent entries amounting to a history of the Contract from the day it commenced to the day it is completed.

The Extras Day Book is supplementary to Contracts Journal, being a record of extra work performed and the value to be charged out in respect of this. It must be kept in close co-operation with the Foreman, who can supply information to the office, for immediate transference into books, thus obviating what is frequently a cause of worry and loss to Builders and Contractors. The Foreman will probably be supplied with a book in which to keep a note of any extra work done by his men and the time spent thereon, and the carbon copies of these pages can be passed on to the book-keeper. Items from this book will later be passed through the Contracts Journal and later posted to the Contracts Ledger.

The Jobbing Order Book and Jobbing Day Book.—The clerk who takes orders for small jobs to be done at short notice, as, for instance, in the case of leaky roofs, burst pipes, broken windows, etc., should keep a Jobbing Order Book. Such small jobs are usually charged at the cost

(*i.e.* materials and time), plus profit, and if the entries are omitted, quite a serious loss can be made in a year. Obviously this book must show details of the customer's name and address, the address at which the work is to be carried out, particulars of the work to be done, and particulars of any arrangements arrived at with the customer. The job will be given a number in this book, having time, material, cost of hire of plant (if any), noted thereon, and later the profit added, and the customer duly charged out.

Copy of the Invoice will pass through the Jobbing Day Book, and eventually be debited to the customer's personal Ledger Account.

Purchase Day Book, in which is entered a list of all incoming invoices on their arrival through the post, in order of date. The left-hand page is divided into columns for details such as Date, Name of Creditor, Goods Purchased, Total Amount of Invoice ; and the right-hand page is analysed, for a later aid to Costing, into columns covering : (*a*) Purchase of goods for stock for use on requisition during the performance of jobs ; (*b*) purchase of goods for direct use on jobs ; (*c*) purchase of additional plant—capital ; (*d*) repairs or additions to plant.

Inward and Outward Credit Day Books.—Both in the case of Sales, and of Purchases, there will be required a record of Credit Notes passed. These will sometimes cover the return of packing cases charged out to a client, or perhaps an excessive charge on which it is agreed to give a rebate, or, on the other hand, it may happen that goods purchased will be returned to the supplier for one of many possible reasons, or that a discount on the original figure is allowed.

Where these items are not too frequent to require individual books, a book-keeper will often use the very end of his Sales Day Book for his Sales Credit Book, and the very end of the Purchase Day Book for the Purchase Credit Book.

Bills Payable and Bills Receivable Book.—The word " Bill " in this instance is meant to convey " Bill of Exchange "—not as is frequently understood—merely an invoice.

A Bill of Exchange is a document issued by one person who agrees to pay another person a certain sum on a certain date. It is often used in business in settlement of debts where lengthy credit is required, and gives the creditor security, as these Bills can be discounted or " cashed " (less a small commission) by a Banker or Broker without delay. The Accountant of the firm issuing a Bill of Exchange must be prepared on the agreed date to have the amount in question withdrawn from the bank account.

If this type of transaction is not frequent, both Bills Receivable and Bills Payable can be kept in the one book, but where it is anticipated that the entries will be frequent, it is advisable to keep the two.

The Journal.—This book takes all " original " entries that do not come within the scope of those already enumerated, and cover such items as

transfers from one account to another, adjustments of errors, transfers of balances at the date of balancing books, etc. Entries in this book vary from the usual type and show the account to be debited, the account to be credited, and a short explanation of the entry.

The Cash Book.—The Cash Book is a "book of original entry."

This book should on the left-hand page be a record of the amounts received and later paid into the Bank Account, and the right-hand page a record of the amounts drawn from the Bank Account; from which it is obvious that the amount of the difference between the two sides (debit and credit of Bank Account) will be the amount remaining at the bank, a confirmation of which figure can be had on reference to the Bank Pass Book, which will be made up at any required date on application.

Amounts drawn to reimburse the Petty Cash Box are posted to the Petty Cash Book, which in its analysis accounts for the amounts in further detail.

Any discounts given or received must be shown in the Cash Book, for later posting to ledger accounts.

The Petty Cash Book.—It is necessary in almost every business to have a small amount of ready cash available, and this should be in the charge of one person only, who will be responsible for accounting for it in a book provided for the purpose. In a small concern, the standard ruling will suffice, and need only set out on the left-hand side such details as date and amount of the receipt of cash for later disbursement, and on the right-hand side the date, description of the expenditure, and amount of each small transaction. Obviously the amount of the difference between the two sides should at any moment be in hand, and it is usual for the person in charge to balance the book monthly and to analyse the items into columns under headings previously agreed upon. The items appearing in the column of "Cash Received" must tally exactly with the items shown in the Cash Book on the credit side allocated to "Petty Cash"; and in the same way items appearing in the column "Cash Received" in the *Postage Book* must tally exactly with the items shown in the Petty Cash Book among the expenditures, and designated "stamps."

The Ledgers.—Each item in the Detail Books above-mentioned are now transferred to Ledgers, and the placing of amounts to the debit or credit of a ledger account from Detail Books is termed "posting." The full details of any transaction having appeared in one or other of the Detail Books, the ledgers only record date, reference, and amount. At any moment the balance owing to a creditor, or by a customer, may be ascertained by taking the total of entries both sides and finding the difference.

The Contracts Ledger will contain an account for each Contract undertaken, and details of whatever the system of costing calls for.

The Sales Ledger contains a Personal Account in the name of each

person or firm to whom invoices have been despatched, and which items have previously been through the Detail Books.

The Purchase Ledger contains an account in the name of any firm or person from whom the materials for stock, or jobs, plant, or machinery have been purchased, details of which have previously been entered in the Purchase Day Book.

The Private Ledger receives only items such as Capital, Drawings, and Impersonal (*e.g.* Salaries, Rent, Telephone, Lighting, Heating) Accounts, and items of a more or less private nature. It is usual to require that this book be kept by a senior member of the staff.

There will, of course, be subsidiary books, not embraced in the book-keeping system, such as:

(*a*) *The Wages and Insurance Book*, compiled from information from General Foremen, and will need to show particulars of each workman's service, analysed into hour, day, weekly, or piece work; and this book will serve to provide details in furtherance of the item " Wages " shown on the outgoing side of the Cash Book.

(*b*) *Stores Record Book*, kept by some competent person, who will keep check on incoming and outgoing stock, and be aided in his task by the fact that he will only release stock on receipt of a requisition slip, and obtain an Advice or Delivery Note for all incoming goods. Where the business requires it, the Costing System can work in conjunction with this record.

The Trial Balance.—At an agreed date, most usually at the end of a year's trading, a Trial Balance is prepared; this is a list of Debit and Credit items as shown in the ledgers at that date, extracted and set out in schedule form.

The two sides of the Trial Balance should agree if the books have been kept correctly and the items posted to the Private Ledger accurately. Thus it serves as an internal check, and, together with the Annual Stock-taking Figures, will provide the data from which to prepare the Profit and Loss Account and the Balance Sheet.

Trading Account.—The items included in the Trading Account come from the figures contained in the Trial Balance and, as is suggested in its name, cover the trading or completed work during the period, the difference in the Debit and Credit sides giving the gross profit or loss.

First take the value of the stock at the starting date of the period, and add all Expenses in the completion of the work, wages, etc. Set against these items the value of the Sales (or completed and charged work) during the period, and the Stock-taking Valuation of the stock at the end of the period.

Profit and Loss Account.—The debit side of this shows items extracted from the Trial Balance for all Expenses, Rent, Rates, Taxes, Salaries, and other Management Expenses, and Charges, and the credit side shows the gross profits made on Contracts or other work from Trading Account.

The difference in the total of the two sides gives the net profit or loss made, which is carried to the Balance Sheet. If a profit has been made on the year's trading, this Account will finally give the amount for distribution into such channels as:

In the case of a limited liability or other company—Dividends to Shareholders, Reserves, etc.

In the case of a partnership—Share between partners, in accordance with any previous agreement.

In the case of a business owned by one individual—Transfer to Capital Account.

The Balance Sheet.—This is made up of the items remaining in the Trial Balance after deleting the figures for the Profit and Loss Account, and are shown under the headings " Liabilities " and " Assets."

Under the first-mentioned heading, give Creditors, Trade and others separately, Bills payable, Loans, Mortgages, and any other liabilities and Capital as at the previous year end, less Drawings. Under the second-mentioned heading, show the Cash in Hand, Cash at Bank, Value of Plant, and Value of Stock, Sundry Debtors, Bills Receivable, Deposits, and Investments.

Costing System.—The Accountant will have to decide the Costing System necessary to the work under his control, and will in all probability arrange that the Time Sheets—weekly or daily—copies of Stores Notes, Requisition Slips, etc., shall be passed to him for abstracting and further analysis, for use in conjunction with the information arranged for in this direction in the set of books.

ESTIMATING

There are several methods of estimating the cost of a building. These may be considered as: Approximate Methods, and Accurate Methods.

Approximate Estimating.—The best-known approximate method is to cube the contents or volume of the building and allow a cost sum per cubic foot.

The building should be measured on plan overall, that is, from corner to corner along the outside walls. The height should be taken as from the bottom of the foundations to a point half-way from wall plate to ridge (in the case of a pitched roof), and to the top of the parapet or 2 feet above the roof (in the case of a flat roof).

If records are available of the cost of a similar building, it is easy to work out a figure of cost per cubic foot, which can then be applied to the costing of the proposed building. For example, a small house with a cubic content of 14,000 cubic feet, priced at 100 per cent. above 1939 costs, might be taken as costing 2*s.* 0*d.* per cubic foot. The total cost would then be, 14,000 × 2 = £1,400.

Another approximate method which is applied to schools, cinemas, hospitals, and institutions, is to apply a cost per unit of seating, beds, etc.

The foregoing methods are obviously not accurate and should only be

used to give a rough-and-ready idea of the cost of a building. They should never be used to calculate a price for tendering.

Accurate Estimating.—The basis of accurate estimating is the Bill of Quantities. By this system all materials and labours are measured and billed according to the Standard Method of Measurement (an agreed method issued under the sanction of the Surveyors' Institution, the National Federation of Building Trades Employers, and the Institute of Builders. Copies are obtainable from the Surveyors' Institution, 12 Gt. George Street, Westminster, S.W.1).

For buildings costing much more than £1,000, quantities are usually prepared by a qualified quantity surveyor employed by the owner under the architect's instructions. The architect sends a copy of the bill of quantities with the prints to each builder who is invited to tender.

After examining the site and taking note of any peculiarities, the builder prices each item in the bill and the total forms the estimate, which is submitted as a tender.

If a bill of quantities is not supplied by the architect, the builder should have quantities taken out, as they form the only reliable basis of estimating.

The Lump-sum Tender for repetitive work such as housing is an exception to this rule, but it only applies to work of a kind which the contractor has already carried out and with which he is thoroughly familiar.

Priced Schedules are used by some Government departments. In these schedules every conceivable item is described and priced. The schedules are printed and obtainable from H.M. Stationery Office. In submitting an estimate the builder is asked to state as a percentage how much less or more he requires than the price listed in the schedule.

Costing.—Accurate prices cannot be entered in a bill of quantities or a schedule of prices unless the builder knows three factors: first, the amount of materials and waste; the labour or time for both skilled and unskilled workers; and the appropriate allowance for overhead charges. These three factors give net cost, and to this must be added the percentage of profit required.

As an example, brickwork is usually measured and billed by the rod. The following is a typical analysis of the cost of one rod of brickwork, though it must be remembered that the amount of material and labour varies with the size of the bricks and the type of work:

	£ s. d.
4,350 bricks at .... per 1,000, delivered	....
19 bushels lime at .... per bushel	....
57 bushels sand at .... per bushel	....
Bricklayer, 70 hours at .... per hour	....
Labourer, 50 hours at .... per hour	....
Net cost	£..........
Add .... per cent. for overhead charges	....
Add .... per cent. for profit	....
Total price per rod for tender	£..........

The cost of materials should be obtained from current quotations. The cost of labour is worked out from two factors: the wage rates in force in the district, and the time it will take to do the job. There are several good books which give analysis tables for the time taken to do almost every conceivable type of job. These are of great assistance to the estimator, but it is advisable to keep records of jobs so that data from one's own experience are collected for use in estimating.

It is also advisable to check the time allowances made when the estimate was prepared by the time actually taken on the job. If there is any error on the wrong side it will be too late to correct it, but the new data will be valuable for future reference.

CHAPTER 12

THE BUILDING INDUSTRY: STANDARD FORMS CONTRACT

ROYAL INSTITUTE OF BRITISH ARCHITECTS

A FORM OF AGREEMENT AND SCHEDULE OF CONDITIONS BUILDING CONTRACTS[1]

This Form is only Applicable where Quantities form Part of the Contract

Articles of Agreement made the . . . . day of 19
between . . . .
of (or whose registered office is situate at) . . . .
. . . .
(hereinafter called " the Employer ") of the one part and
. . . .
of (or whose registered office is situate at) . . . .
. . . .

6d. Stamp to be impressed here if contract is under hand.

10s. Stamp to be impressed here if contract is under seal.

(hereinafter called " the Contractor ") of the other part. WHEREAS the Employer is desirous of[2] . . . .
. . . .
(hereinafter called " the Works ") at . . . .
and has caused Drawings and Bills of Quantities showing and describing the work to be done to be prepared by or under the direction of. . . . . .
. . . .

[1] *This Form is only applicable where quantities form part of the Contract, and requires to be varied and to have the blanks and appendix filled in to meet the special circumstances of each Contract.*

To be obtained at: The Royal Institute of British Architects, 66 Portland Place, London, W.1; The National Federation of Building Trades Employers, 82 New Cavendish Street, London, W.1. July, 1939 (Revised 1945). Price 2s.

[2] *State nature of intended works.*

of ....
his Architect : AND WHEREAS the said Drawings numbered .... to .... inclusive (hereinafter referred to as " the Contract Drawings ") and the said Bills of Quantities have been signed by or on behalf of the parties hereto :

Now it is hereby agreed as follows:

(1) For the consideration hereinafter mentioned the Contractor will upon and subject to the Conditions annexed hereto execute and complete the Works shown upon the said Drawings and described by or referred to in the said Bills of Quantities and Conditions.

(2) The Employer will pay to the Contractor the sum of .... [£ : :] (hereinafter referred to as " the Contract Sum ") or such other sum as shall become payable hereunder at the times and in the manner specified in the said Conditions.

(3) The term " the Architect " in the said Conditions shall mean the said ....
of ....
or, in the event of his death or ceasing to be the Architect for the purpose of this contract, such other person as shall be nominated for that purpose by the Employer, not being a person to whom the Contractor shall object for reasons considered to be sufficient by the Arbitrator mentioned in the said Conditions. Provided always that no person subsequently appointed to be Architect under this contract shall be entitled to disregard or overrule any decision or approval or direction given or expressed by the Architect for the time being.

(4) The term " the Surveyor " in the said Conditions shall mean ....
of ....
or, in the event of his death or ceasing to be the Surveyor for the purpose of this contract, such other person as shall be nominated for that purpose by the Employer or the Architect on his behalf, not being a person to

CHAPTER 12

THE BUILDING INDUSTRY: STANDARD FORMS OF CONTRACT

ROYAL INSTITUTE OF BRITISH ARCHITECTS

A FORM OF AGREEMENT AND SCHEDULE OF CONDITIONS FOR BUILDING CONTRACTS[1]

This Form is only Applicable where Quantities form Part of the Contract

Articles of Agreement made the .... day of .... 19 ....
between ....
of (or whose registered office is situate at) ....
....
(hereinafter called " the Employer ") of the one part and
....
of (or whose registered office is situate at) ....
....

6*d*. Stamp to be impressed here if contract is under hand.
10*s*. Stamp to be impressed here if contract is under seal.

(hereinafter called " the Contractor ") of the other part. WHEREAS the Employer is desirous of[2] ....
....
(hereinafter called " the Works ") at ....
and has caused Drawings and Bills of Quantities showing and describing the work to be done to be prepared by or under the direction of......
....

[1] This Form is only applicable where quantities form part of the Contract, and requires to be varied and to have the blanks and appendix filled in to meet the special circumstances of each Contract.

To be obtained at: The Royal Institute of British Architects, 66 Portland Place, London, W.1; The National Federation of Building Trades Employers, 82 New Cavendish Street, London, W.1. July, 1939 (Revised 1945). Price 2*s*.

[2] State nature of intended works.

of ....
his Architect : AND WHEREAS the said Drawings numbered ....
to .... inclusive (hereinafter referred to as " the Contract Drawings ") and the said Bills of Quantities have been signed by or on behalf of the parties hereto :

Now it is hereby agreed as follows:

(1) For the consideration hereinafter mentioned the Contractor will upon and subject to the Conditions annexed hereto execute and complete the Works shown upon the said Drawings and described by or referred to in the said Bills of Quantities and Conditions.

(2) The Employer will pay to the Contractor the sum of ....
....
[£ : :] (hereinafter referred to as " the Contract Sum ") or such other sum as shall become payable hereunder at the times and in the manner specified in the said Conditions.

(3) The term " the Architect " in the said Conditions shall mean the said ....
of ....
or, in the event of his death or ceasing to be the Architect for the purpose of this contract, such other person as shall be nominated for that purpose by the Employer, not being a person to whom the Contractor shall object for reasons considered to be sufficient by the Arbitrator mentioned in the said Conditions. Provided always that no person subsequently appointed to be Architect under this contract shall be entitled to disregard or overrule any decision or approval or direction given or expressed by the Architect for the time being.

(4) The term " the Surveyor " in the said Conditions shall mean ......
....
of ....
or, in the event of his death or ceasing to be the Surveyor for the purpose of this contract, such other person as shall be nominated for that purpose by the Employer or the Architect on his behalf, not being a person to

whom the Contractor shall object for reasons considered to be sufficient by the Arbitrator mentioned in the said Conditions.

[1] In Witness whereof the parties hereto have hereunto set their hands the day and year first above written.

Signed by the said

....

....

....

in the presence of

Name ....

Address ....

Description ....

Signed by the said

....

....

....

in the presence of

Name ....

Address ....

Description ....

The Conditions hereinbefore referred to

Note.—Alternatives must be struck out in Clauses 10, 15, and 24 (*d*).

(1) *Scope of Contract.*—The Contractor shall carry out and complete the Works in accordance with this contract in every respect in accordance with the directions and to the reasonable satisfaction of the Architect. If the Contractor shall find any discrepancy in or divergence between the Contract Drawings and/or Bills of Quantities he shall immediately refer the same in writing to the Architect and specifically apply in writing for any necessary instructions from the Architect in relation thereto. The Architect may in his absolute discretion and from time to time issue further drawings, details, and/or written instructions, written directions and written explanations (all of which are in these Conditions collectively referred to as " Architect's Instructions ") in regard to :

(*a*) The variation or modification of the design, quality, or quantity of the Works or the addition or omission or substitution of any work.

(*b*) Any discrepancy in or divergence between the Contract Drawings and/or Bills of Quantities.

[1] If the contract is to be executed under seal, this clause and the words following it must be altered accordingly.

(*c*) The removal from the site of any materials brought thereon by the Contractor and the substitution of any other materials therefor.

(*d*) The removal and/or re-execution of any works executed by the Contractor.

(*e*) The postponement of any work to be executed under the provisions of this contract.

(*f*) The dismissal from the Works of any person employed thereupon.

(*g*) The opening up for inspection of any work covered up.

(*h*) The amending and making good of any defects under clause 12 of these Conditions.

If any verbal instructions, directions, or explanations involving a variation are given to the Contractor or his foreman upon the Works by the Architect or by the Clerk of Works appointed by the Employer, such instructions, directions, or explanations shall be confirmed in writing by the Contractor to the Architect within seven days, and if not dissented from in writing by the Architect to the Contractor within a further seven days shall be deemed to be Architect's Instructions. The Contractor shall forthwith comply with all Architect's Instructions. If compliance with Architect's Instructions involves any variation, such variation shall be dealt with under clause 9 of these Conditions and the value thereof shall be added to or deducted from the Contract Sum.

If compliance with Architect's Instructions involves the Contractor in loss or expense beyond that provided for in or reasonably contemplated by this contract, then, unless such instructions were issued by reason of some breach of this contract by the Contractor, the amount of such loss or expense shall be ascertained by the Architect and shall be added to the Contract Sum.

If within seven days after receipt of a written notice from the Architect requiring compliance with Architect's Instructions the Contractor does not comply therewith, the Employer may employ and pay other persons to execute any work whatsoever which may be necessary to give effect to such instructions and all costs incurred in connection therewith shall be recoverable from the Contractor by the Employer as a debt or may be deducted by him from any monies due or to become due to the Contractor under this contract.

(2) *Drawings and Bills of Quantities, etc.*—The Contractor shall furnish to the Architect on the signing of this contract a fully priced copy of the Bills of Quantities, unless it has already been furnished. The Contract Drawings and the said priced copy shall remain in the custody of the Architect or of the Surveyor so as to be available at all reasonable times for the inspection of the Employer or the Contractor. The Architect without charge to the Contractor shall on the signing of this contract furnish him with two copies of the Contract Drawings and of blank Bills of Quantities, and shall within a reasonable time also furnish him with

such further drawings as are reasonably necessary to enable him to carry out all Architect's Instructions and with any further details which in the opinion of the Architect are necessary for the execution of any part of the work. The Contractor shall also be entitled to receive from the Architect without charge on or before the signing of this contract two copies of a Specification for use in carrying out the Works, but nothing contained therein shall impose upon the Contractor any obligations beyond those imposed by the contract documents, namely, by the Contract Drawings, Bills of Quantities, and Conditions referred to in the Articles of Agreement. The Contractor shall keep one copy of the Contract Drawings and Specification on the Works so as to be available to the Architect or his representative at all reasonable times. Upon receiving final payment the Contractor shall forthwith return to the Architect all drawings and specifications bearing his name.

None of the documents hereinbefore mentioned shall be used by either of the parties hereto for any purpose other than this contract, and neither the Employer, the Architect, nor the Surveyor shall divulge or use except for the purposes of this contract any information contained in the priced Bills of Quantities.

(3) *Local and Other Authorities' Notices and Fees.*—(*a*) The Contractor shall comply with and give all notices required by any Act of Parliament or by any regulation or by-law of any local authority or of any public service company or authority who have any jurisdiction with regard to the Works or with whose systems the same are or will be connected, and he shall pay and indemnify the Employer against any fees or charges legally demandable under such Act of Parliament, regulation, or by-law in respect of the Works; provided that the said fees and charges if not expressly included in the Contract Sum or stated by way of provisional sum shall be added to the Contract Sum.

(*b*) The Contractor before making any variation from the Contract Drawings or Bills of Quantities necessitated by such compliance shall give to the Architect written notice specifying and giving the reason for such variation and applying for instructions in reference thereto.

(*c*) If the Contractor within seven days of having applied for the same does not receive such instructions, he shall proceed with the work conforming to the provision, regulation, or by-law in question and any variation thereby necessitated shall be deemed to be a variation under clause 9 of these Conditions.

(4) *Setting out of Works.*—The Architect shall furnish to the Contractor either by way of carefully dimensioned drawings or by personal supervision at the time of setting out the Works, such information as shall enable the Contractor to set out the enclosing walls of the building at ground level after which the Contractor shall be responsible and shall at his own cost amend any errors arising from his own inaccurate setting out, unless the Architect shall otherwise direct.

(5) *Materials and Workmanship to Conform to Description.*—All materials

and workmanship shall so far as procurable be of the respective kinds described in the Bills of Quantities and the Contractor shall upon the request of the Architect furnish him with vouchers to prove that the materials comply therewith. The Contractor shall arrange for and/or carry out any test of any materials which the Architect may in writing require and the cost thereof shall be added to the Contract Sum unless provided for in the Bills of Quantities or unless the test shows that the said materials are not in accordance with this contract.

(6) *Foreman.*—The Contractor shall constantly keep upon the Works a competent general foreman and any instructions given to him by the Architect shall be deemed to be given to the Contractor in pursuance of clause 1 of these Conditions.

(7) *Access for Architect to Works.*—The Architect and his representatives shall at all reasonable times have access to the Works and/or to the workshops or other places of the Contractor where work is being prepared for the contract, and in so far as work in virtue of any sub-contract is to be so prepared in workshops or other places of a sub-contractor (whether or not a nominated Sub-Contractor as defined in clause 21 of these Conditions) the Contractor shall also by a term in the sub-contract so far as possible secure a similar right of access to those workshops or places for the Architect and his representatives and shall do all things reasonably necessary to make such right effective.

(8) *Clerk of Works.*—The Employer shall be entitled to appoint a Clerk of Works whose duty shall be to act solely as inspector on behalf of the Employer under the directions of the Architect and the Contractor shall afford every facility for the performance of that duty.

(9) *Ascertainment of Prices for Variations.*—No variation shall vitiate this contract. All variations authorised by the Architect or subsequently sanctioned by him in writing shall be measured and valued by the Surveyor who shall give to the Contractor an opportunity of being present at the time of such measurement and of taking such notes and measurements as the Contractor may require. The Contractor shall be supplied with a copy of the priced Bills of Variations not later than the end of the Period of Final Measurement stated in the appendix to these Conditions and before the date of the Architect's certificate in respect of such variations, and the valuation thereof unless previously or otherwise agreed shall be made in accordance with the following rules :

(*a*) The prices in the Bills of Quantities mentioned in clause 2 of these Conditions shall determine the valuation of extra work of similar character executed under similar conditions as work priced therein ;

(*b*) The said prices, where extra work is not of a similar character or executed under similar conditions as aforesaid, shall be the basis of prices for the same so far as may be reasonable, failing which a fair valuation thereof shall be made ;

(*c*) Where extra work cannot properly be measured and valued the Contractor shall be allowed day-work prices

(i) at the rates, if any, inserted by the Contractor in the Bills of Quantities above mentioned or in the Form of Tender ; or

(ii) when no such rates have been inserted, at the rates stated in the National Schedule of Daywork Charges agreed between the Chartered Surveyors' Institution and the National Federation of Building Trades Employers ; or

(iii) where rates have been agreed between the said Institution and the appropriate body representing any sub-contracting trade, at those rates (whether in the last-mentioned case the work be done by the Contractor or by a sub-contractor) ;

Provided that in any case vouchers specifying the time daily spent upon the work (and if required by the Architect the workmen's names) and the materials employed shall be delivered for verification to the Architect or his authorised representative not later than the end of the week following that in which the work has been executed ;

(*d*) The prices in the above-mentioned Bills of Quantities shall determine the valuation of items omitted ; provided that if omissions substantially vary the conditions under which any remaining items of work are carried out the prices for such remaining items shall be valued under rule (*b*) of this clause.

The measurement and valuation of the Works shall be completed within the Period of Final Measurement stated in the appendix and if no other period is so stated then within three months from the practical completion of the Works, and effect shall be given to the measurement and valuation of variations by adjustment of the Contract Sum.

(10) *Bills of Quantities.*—The quality and quantity of the work included in the Contract Sum shall be deemed to be that which is set out in the Bills of Quantities mentioned in clause 2 of these Conditions which Bills unless otherwise expressly stated shall be deemed to have been prepared in accordance with the principles of the Standard Method of Measurement of Building Works last before issued by the Chartered Surveyors' Institution and the National Federation of Building Trades Employers, but save as aforesaid nothing contained in the said Bills of Quantities shall override, modify, or affect in any way whatsoever the application or interpretation of that which is contained in these Conditions.

Any error in description or in quantity in or omission of items from the Bills of Quantities shall not vitiate this contract but shall be rectified and treated as a variation.

[1] (A) The fees for preparing the Bills of Quantities and the Surveyor's expenses (if any) stated therein shall be paid by the Contractor to the Surveyor immediately after receiving the amount of the certificate in which they are included. The fees and expenses chargeable for the measuring and valuing of variations shall be included in the Architect's

[1] In Clause 10 strike out (A) or (B) as the case may require.

penultimate certificate and shall be paid by the Contractor to the Surveyor out of and immediately after payment by the Employer of the amount of that certificate. If the Contractor fails or neglects so to pay those fees, the Employer may do so if he sees fit, and if he has paid the fees in pursuance of this clause he may deduct the amount from any sums due or to become due to the Contractor.

[1] (B) The fees and expenses for preparing the Bills of Quantities and for measuring and valuing variations shall be paid by the Employer.

(11) *Unfixed Materials when taken into Account to be the Property of the Employer.*—Where in any certificate of which the Contractor has received payment the Architect has in accordance with clause 24 (*b*) of these Conditions included the value of any unfixed materials and goods intended for and placed on or adjacent to the Works, such materials and goods shall become the property of the Employer and shall not be removed except for use upon the Works unless the Architect has authorised in writing such removal, and the Contractor shall be responsible for any loss of or damage to the same.

(12) *Defects after Completion.*—Any defects, shrinkage, or other faults which shall appear within the Defects Liability Period stated in the appendix to these Conditions and shall be due to materials or workmanship not in accordance with this contract or to frost occurring before completion of the Works, shall within a reasonable time after receipt of the Architect's written instructions in that behalf be made good by the Contractor and (unless the Architect shall otherwise direct) at his own cost; provided that the Contractor shall not be required to make good at his own cost any damage by frost which may appear after completion, unless the Architect shall decide that such damage is due to injury which took place before completion.

(13) *Assignment or Sub-letting.*—The Contractor shall not without the written consent of the Architect assign this contract or sub-let any portion of the Works; provided that such consent shall not be unreasonably withheld to the prejudice of the Contractor.

(14) *Injury to Persons and Property.*—(*a*) *Injury to Persons.* The Contractor shall be solely liable for and shall indemnify the Employer in respect of and shall insure against any liability, loss, claim, or proceedings whatsoever arising under any statute (other than the Workmen's Compensation and Employers' Liability Acts) or at common law in respect of personal injury to or the death of any person whomsoever arising out of or in the course of or caused by the execution of the Works, unless due to any act or neglect of the Employer or of any person for whom the Employer is responsible.

(*b*) *Workmen's Compensation.* The Contractor shall insure himself against any liability arising under the Employers' Liability Acts or the Workmen's Compensation Acts (otherwise than under section 6 of the Workmen's Compensation Act, 1925) and shall procure that every sub-

[1] In Clause 10 strike out (A) or (B) as the case may require.

contractor (whether or not a sub-contractor nominated in accordance with clause 21 of these Conditions) shall be insured against any such liability.

(*c*) *Injury to Property.* The Contractor shall be liable for and shall indemnify the Employer against and, where so provided in the Bills of Quantities, shall insure against any liability, loss, claim, or proceedings in respect of any injury or damage whatsoever to any property real or personal in so far as such injury or damage arises out of or in the course of or by reason of the execution of the Works, and provided always that the same is due to any negligence, omission, or default of the Contractor, his servants or agents or of any sub-contractor or to any circumstances within the Contractor's control; and subject also as regards loss or damage by fire to the provisions contained in clause 15 of these Conditions.

(*d*) To the extent that the Contractor shall have been required under the foregoing sub-clauses to insure himself or to procure that any sub-contractor shall be insured, the Contractor shall produce or cause such sub-contractor to produce as the case may be the relevant policy or policies and premium receipts as and when required by the Architect; should the Contractor make default in so doing, the Employer may insure against any risk with respect to which the default shall have occurred and may deduct the premiums paid from any monies due or to become due to the Contractor.

[1] (15) *Insurance.*—(A) The Contractor shall in the joint names of the Employer and Contractor insure against loss and damage by fire for the full value thereof (plus $8\frac{1}{2}$ per cent. to cover Architect's and Surveyor's fees) all work executed and materials and goods upon the site including any unfixed materials or goods which by virtue of clause 11 of these Conditions have become the property of the Employer and shall keep such work, materials, and goods so insured until the Works are delivered up; such insurance shall be with a company or companies approved by the Architect and the Contractor shall deposit with him the policies and premium receipts; should the Contractor make default the Employer may insure as aforesaid and deduct the premiums paid from any monies due or to become due to the Contractor.

The Contractor shall upon settlement of any claim under the policies aforesaid proceed with due diligence to rebuild or repair the Works and replace or repair the materials or goods destroyed or injured. All monies received under such policies (less the said $8\frac{1}{2}$ per cent.) are to be paid to the Contractor by instalments under certificates of the Architect and the Contractor shall not be entitled to any payment in respect of the rebuilding or repair of the Works or the replacement or repair of the materials or goods destroyed or injured other than the monies received under the said policies.

[1] (B) The existing structures and the Works and unfixed materials

[1] In Clause 15 sub-paragraph (A) applies to a new building and sub-paragraph (B) to an existing building to be altered or extended; therefore strike out sub-paragraph (A) or (B) as the case may require.

(except plant, tools, and equipment) shall be at the sole risk of the Employer as regards loss or damage by fire and the Employer shall maintain a proper policy of insurance against that risk, which policy and the receipt for the last paid premium for its renewal he shall upon request produce for inspection by the Contractor and, if any loss or damage affecting the Works is so occasioned by fire, the Employer shall pay to the Contractor the full value of all work and materials then executed and delivered calculated as provided in clause 9 of these Conditions, and this contract as to subsequent work may at the option of either party be determined by notice by registered post from either party to the other, provided that on receipt of such a notice the other party may himself give notice in pursuance of clause 26 of these Conditions that a dispute or difference has arisen on the question whether such determination will be just and equitable.

If the Employer shall have failed upon request to produce any receipt showing the policy to be effective the Contractor shall be entitled to insure the said structures and Works against the said risks and upon production of the receipts for any premiums to add their amount to the Contract Sum.

(16) *Date for Possession and Completion.*—On or before the Date for Possession stated in the appendix to these Conditions possession of the site shall be given to the Contractor who shall thereupon begin the Works forthwith and regularly and diligently proceed with the same and shall complete the same on or before the Date for Completion stated in the said appendix subject nevertheless to the provisions for extension of time contained in clause 18 of these Conditions.

(17) *Damages for Non-completion.*—If the Contractor fails to complete the Works by the date stated in the appendix to these Conditions or within any extended time fixed under clause 18 of these Conditions and the Architect certifies in writing that in his opinion the same ought reasonably so to have been completed, the Contractor shall pay or allow to the Employer a sum calculated at the rate stated in the said appendix as Liquidated and Ascertained Damages for the period during which the said Works shall so remain or have remained incomplete, and the Employer may deduct such damages from any monies otherwise payable to the Contractor under this contract.

(18) *Delay and Extension of Time.*—If in the opinion of the Architect the Works be delayed

(i) by *force majeure*, or

(ii) by reason of any exceptionally inclement weather, or

(iii) by reason of such loss or damage by fire as is referred to in clause 15 of these Conditions, or

(iv) by reason of civil commotion, local combination of workmen, strike, or lockout affecting any of the trades employed upon the Works, or

(v) by reason of Architect's Instructions given in pursuance of clause 1 of these Conditions, or

(vi) because the Contractor has not received in due time necessary instructions from the Architect for which he shall have specially applied in writing, or

(vii) by delay on the part of nominated Sub-Contractors or nominated Suppliers which the Contractor has in the opinion of the Architect taken all practicable steps to avoid or reduce, or

(viii) by delay on the part of other contractors or tradesmen engaged by the Employer in executing work not forming part of this contract,

then in any such case the Architect shall make a fair and reasonable extension of time for completion of the Works. Upon the happening of any such event causing delay the Contractor shall immediately give notice thereof in writing to the Architect, but he shall nevertheless use constantly his best endeavours to prevent delay and shall do all that may reasonably be required to the satisfaction of the Architect to proceed with the Works.

(19) *Determination by Employer.*—(*a*) *Default.* If the Contractor shall make default in any of the following respects, *viz.*:

(1) If without reasonable cause he wholly suspends the Works before completion,

(2) If he fails to proceed with the Works with reasonable diligence,

(3) If he refuses or persistently neglects to comply with a notice in writing from the Architect requiring him to remove defective work or improper materials and by such refusal or neglect the Works are materially affected,

and if he shall continue such default for fourteen days after a notice by registered post specifying the default has been given to him by the Architect, the Employer may, without prejudice to any other rights or remedies, thereupon by notice by registered post determine the employment of the Contractor under this contract; provided that notice in pursuance of this clause shall not be given unreasonably or vexatiously and shall be void if the Employer is at the time of the notice in breach of this contract.

(*b*) *Bankruptcy of Contractor.* If the Contractor commits an act of bankruptcy or being a company enters into liquidation whether compulsory or voluntary except liquidation for the purposes of reconstruction the Employer may, without prejudice to any other rights or remedies, by notice by registered post determine the employment of the Contractor under this contract.

(*c*) In either of the cases for which the two preceding sub-clauses provide the following shall be the respective rights and duties of the Employer and Contractor, *viz.*:

(1) The Employer may employ and pay another contractor or other person or persons to carry out and complete the Works and he or they may enter upon the site and use all temporary buildings, plant, machinery, appliances, goods, and materials thereon, and may

purchase all materials necessary for the carrying out and completion of the Works.

(2) The Contractor shall, if so required by the Employer or Architect, assign to the Employer without further payment the benefit of any agreement for the supply of materials and/or for the execution of any works for the purposes of this contract and the Employer shall pay for any such materials or works supplied or executed under such agreement after the said determination the price fixed by such agreement in so far as it has not been already paid by the Contractor.

(3) The Contractor shall during the execution or after the completion of the Works under this clause remove from the site as and when required, within such reasonable time as the Architect may in writing specify, any temporary buildings, plant, machinery, appliances, goods, or materials belonging to or hired by him, and in default the Employer may (without being responsible for any loss or damage) remove and sell any such property of the Contractor, holding the proceeds less all costs incurred to the credit of the Contractor.

(4) Until after completion of the Works under this clause the Employer shall not be bound by any other provision of this contract to make any payment to the Contractor, but upon such completion as aforesaid and the verification within a reasonable time of the accounts therefor the Architect shall certify the amount of expenses properly incurred by the Employer and, if such amount added to the monies paid to the Contractor before such determination exceeds the total amount which would have been payable on due completion in accordance with this contract, the difference shall be a debt payable to the Employer by the Contractor; and if the said amount added to the said monies be less than the said total amount, the difference shall be a debt payable by the Employer to the Contractor.

(20) *Determination by Contractor.*—(1) If the Employer within the period after the presentation of any certificate of the Architect which is named in the appendix to these Conditions and thereafter for seven clear days after written notice from the Contractor does not pay to the Contractor the amount due on that certificate, or if the Employer interferes with or obstructs the issue of any such certificate, or if he commits an act of bankruptcy or being a company enters into liquidation whether compulsory or voluntary except liquidation for purposes of reconstruction, or if the whole or substantially the whole of the Works (other than work required under clause 12 of these Conditions) is delayed for three months by one or more of the causes, other than local combination of workmen, strike, or lockout, which are named in clause 18 of these Conditions, the Contractor may, without prejudice to any other rights or remedies, thereupon by notice by registered post to the Employer or Architect determine the employment of the Contractor under this contract.

(2) Upon such determination, then without prejudice to the accrued rights or remedies of either party or to any liability of the classes men-

tioned in clause 14 of these Conditions which may accrue either before the Contractor or any sub-contractors shall have removed his or their temporary buildings, plant, machinery, appliances, goods, or materials or by reason of his or their so removing the same, the respective rights and liabilities of the Contractor and the Employer shall be as follows, *viz.*:

(*a*) The Contractor shall with all reasonable dispatch and in such manner and with such precautions as will prevent injury or damage of the classes for which before such determination he was liable under clause 14 of these Conditions remove from the site all his temporary buildings, plant, machinery, appliances, goods, and materials and shall give facilities for his sub-contractors to do the same, but subject always to the provisions of sub-clause (*b*) (iii) of this clause.

(*b*) The Contractor shall be paid by the Employer:

(i) The contract value of the Works completed at the date of such determination subject to clause 9 of these Conditions.

(ii) The value of work begun and executed but not completed at the date of such determination, the value being ascertained *mutatis mutandis* in accordance with clause 9 of these Conditions.

(iii) The cost of materials or goods properly ordered for the Works for which the Contractor shall have paid or of which the Contractor is legally bound to accept delivery, and on such payment by the Employer any materials or goods so paid for shall become the property of the Employer.

(iv) The reasonable cost of removal under sub-clause (*a*) of this clause.

(v) Any loss or damage caused to the Contractor owing to such determination.

Provided that in addition to all other remedies the Contractor upon such determination may take possession of and shall have a lien upon all unfixed materials intended for the Works, which may have become the property of the Employer under this contract until payment of all monies due to the Contractor from the Employer.

(21) *Nominated Sub-Contractors.*—Where prime cost or provisional sums are included in the Bills of Quantities for persons to be nominated or selected by the Architect to supply and fix materials or to execute work on the site,

(*a*) Such sums shall be deemed to include $2\frac{1}{2}$ per cent. cash discount and shall be expended in favour of such persons as the Architect shall direct, and all specialists or others who have been nominated or selected by the Architect are hereby declared to be sub-contractors employed by the Contractor and are referred to in these conditions as "nominated Sub-Contractors." Provided that no nominated Sub-Contractor shall be employed upon or in connection with the Works against whom the Contractor shall make reasonable objection or (save where the Architect and Contractor shall otherwise agree) who will not enter into a sub-contract providing:

(1) That the nominated Sub-Contractor shall indemnify the Contractor against the same obligations in respect of the sub-contract as those for which the Contractor is liable in respect of this contract.

(2) That the nominated Sub-Contractor shall indemnify the Contractor against claims in respect of any negligence by such Sub-Contractor, his servants or agents or any misuse by him or them of any scaffolding or other plant or any claim under the Workmen's Compensation Acts or the Employers' Liability Acts, and shall insure himself against any such liability under the said Acts and produce the policy or policies and premium receipts as and when required by the Architect.

(3) That payment in respect of any work, materials, or goods comprised in the sub-contract shall not be due until receipt by the Contractor of the Architect's certificate under clause 24 of these Conditions which includes the value of such work, materials or goods, and shall when due be subject to a discount for cash of $2\frac{1}{2}$ per cent.

(4) That the Architect and his representatives shall have a right of access to the workshops and other places of the nominated Sub-Contractor as mentioned in clause 7 of these Conditions.

(*b*) The sums directed by the Architect to be paid to nominated Sub-Contractors for work, materials, or goods comprised in the sub-contract shall be paid by the Contractor within 14 days of receiving from the Architect a certificate including the value of such work, materials, or goods less only (i) any retention money which the Contractor may be entitled to deduct, and (ii) a cash discount of $2\frac{1}{2}$ per cent.

(*c*) Before any such certificate is issued to the Contractor he shall, if requested by the Architect, furnish to him reasonable proof that all nominated Sub-Contractors' accounts included in previous certificates have been duly discharged, in default whereof the Employer may pay such accounts upon a certificate of the Architect and deduct the amount so paid from any sums otherwise payable to the Contractor.

(*d*) If the Architect desires to secure final payment to any nominated Sub-Contractor before final payment is due to the Contractor, and if such Sub-Contractor has satisfactorily indemnified the Contractor against any latent defects, then the Architect may in a certificate under clause 24 of these Conditions include an amount to cover the said final payment, and thereupon the Contractor shall pay to such Sub-Contractor the amount so certified less only a cash discount of $2\frac{1}{2}$ per cent. and the limit of retention money named in clause 24 of these Conditions and/or the appendix shall be reduced in proportion to the amount so certified and the Contractor shall be discharged from all liability for the work or materials covered by such certificate except for any latent defects.

(*e*) Neither the existence nor the exercise of the foregoing powers nor anything else contained in these Conditions shall render the Employer in any way liable to any nominated Sub-Contractor.

(*f*) Where the Contractor in the ordinary course of his business directly carries out works for which prime cost or provisional sums are included in the Bills of Quantities and where items of such works are set out in the appendix to these Conditions and the Architect is prepared to receive tenders from the Contractor for such items, the Contractor shall be permitted to tender for the same or any of them without prejudice to the Employer's right to reject the lowest or any tender. If the Contractor's tender is accepted, he shall not sublet the work without the consent of the Architect.

(22) *Nominated Suppliers.*—Where prime cost or provisional sums are included in the Bills of Quantities in respect of any materials or goods to be fixed by the Contractor.

(*a*) Such sums shall be deemed to include 5 per cent. cash discount and the term prime cost or the abbreviation P.C. as used in these Conditions shall be understood to mean the net cost to be defrayed as a prime cost or to be defrayed from the said provisional sums as the case may be after deducting any trade or other discount except a cash discount of 5 per cent., and shall include the cost of packing and of carriage and delivery. Provided that, where in the opinion of the Architect the Contractor has incurred expense for special packing or special carriage, the Architect shall so inform the Surveyor who shall allow for the same as part of the sums actually paid by the Contractor.

(*b*) All specialists, merchants, tradesmen, or others who have been nominated or selected by the Architect to supply such materials or goods are hereby declared to be suppliers to the Contractor and are referred to in these Conditions as "nominated Suppliers." All payments by the Contractor for such materials or goods shall be in full and shall be paid within 30 days of the end of the month during which delivery is made less only a cash discount of 5 per cent. if so paid. Provided that the Contractor shall not be bound to place an order for the supply of materials or goods with a nominated Supplier who will not agree to allow such 5 per cent. discount for cash.

(23) *Artists and Tradesmen.*—The Contractor shall permit the execution of work not provided for in the Bills of Quantities by artists, tradesmen, or others engaged by the Employer. Every such person shall for the purposes of clause 14 of these Conditions be deemed to be a person for whom the Employer is responsible and not to be a sub-contractor.

(24) *Certificates and Payments.*—(*a*) At the Period of Interim Certificates named in the appendix to these Conditions interim valuations shall be made whenever the Architect considers them necessary, and the Contractor shall subject to clause 21 of these Conditions be entitled to receive within ten days of his written application for the same a certificate from the Architect stating the amount due to the Contractor from the Employer, and shall on presenting any such certificate to the Employer be entitled to payment therefor within the period named in the appendix.

(*b*) The amount so due shall, subject to clause 21 (*c*) of these Conditions and to any agreement between the parties as to stage payments, be the total value of the work properly executed and of the materials and goods delivered upon the site for use in the Works up to and including a date not more than seven days before the date of the said certificate, less the amount to be retained by the Employer (as hereinafter provided) and less any instalments previously paid under this clause. Provided that such certificate shall only include the value of the said materials and goods as and from such time as they are reasonably, properly, and not prematurely brought upon the site and then only if adequately stored and/or protected against weather or other casualties.

(*c*) The amount which may be retained by the Employer in virtue of this clause shall be the percentage of the value of the work and materials aforesaid which is named in the appendix as Percentage of Certified Value Retained and up to the amount there named as Limit of Retention Fund (which in neither case shall exceed 10 per cent.). Provided that where the limit named in the appendix or the limit reduced in pursuance of clause 21 of these Conditions, as the case may be, has been reached, the full value of the work and materials shall be certified by the Architect.

(*d*) [1] (A) The amounts retained in virtue of this clause shall constitute a fund called the Retention Fund which shall be dealt with as may be agreed and in default of agreement in the following manner:

The amounts retained to constitute the Retention Fund shall forthwith as they are so retained be paid into the Bank named in the appendix, and shall be placed in an account in the joint names of the Employer and Contractor, on deposit at interest, and the principal and interest shall be held upon trust for the Employer as security for the due completion of the Works, until these are practically completed.

On practical completion of the Works the Contractor shall subject to clause 17 of these Conditions be entitled to a certificate for one moiety of the Fund, including interest accrued to date, the other moiety in the said joint names being held upon trust for the purpose aforesaid until the issue of the Architect's final certificate, whereupon the said moiety and further interest thereon shall be paid to the Contractor. Provided that if the Employer shall commit an act of bankruptcy or being a company shall enter into liquidation whether compulsory or voluntary except liquidation for the purposes of reconstruction or shall repudiate this contract or the Contractor shall duly determine his employment thereunder, the said Retention Fund in the said joint names (including interest) shall be held upon trust for and the same shall be forthwith paid to the Contractor by the Employer or other person legally entitled to deal with the same.

[1] (B) The amounts retained in virtue of this clause shall be dealt with in the following manner:

On practical completion of the Works the Contractor shall subject to clause 17 of these Conditions be entitled to a certificate for one moiety

[1] In Clause 24 (*d*) strike out (A) or (B) as the case may require.

of the total amounts so retained, and the other moiety shall be paid to the Contractor upon the issue of the Architect's final certificate.

(*e*) In the settlement of accounts the amounts paid or payable by the Contractor to nominated Sub-Contractors or nominated Suppliers (including the cash discounts mentioned in clauses 21 and 22 respectively of these Conditions) and the value of any works executed by the Contractor in pursuance of clause 21 (*f*) of these Conditions shall be set against the prime cost or provisional sum or sums, or sums for additional works mentioned in the Bills of Quantities as the case may be, and the balance, after allowing *pro rata* for the Contractor's profit at the rates contained in the Contractor's original estimate as shown in the priced Bills of Quantities, shall be added to or deducted from the Contract Sum. Provided that no deductions shall be made by or on behalf of the Employer in respect of any damages paid or allowed by any sub-contractor or supplier to the Contractor, the intention being that the Contractor and not the Employer shall have the benefit of any such damages.

(*f*) Upon expiration of the Defects Liability Period stated in the appendix to these Conditions or upon completion of making good defects under clause 12 of these Conditions, whichever is the later, the Architect shall issue a final certificate of the value of the Works executed by the Contractor and such final certificate, save in cases of fraud, dishonesty, or fraudulent concealment relating to the Works or materials or to any matter dealt with in the certificate and save as regards all defects and insufficiencies in the Works or materials which a reasonable examination would not have disclosed, shall be conclusive evidence as to the sufficiency of the said Works and materials.

(*g*) Save as aforesaid no certificate of the Architect shall of itself be conclusive evidence that any Works or materials to which it relates are in accordance with this contract.

(25) *Fluctuations.*—(A) The Contract Sum shall be deemed to have been calculated in the manner set out below and shall be subject to variation in the events specified hereunder.

(1) (*a*) The prices contained in the priced Bills of Quantities referred to in clause 2 of these Conditions (hereinafter in this clause called "the priced Bills") are based upon the rates of wages and other emoluments and expenses (including the cost of workmen's compensation insurance and Third Party Insurance) payable by the Contractor to workpeople engaged upon or in connection with the Works in accordance with the rules or decisions of the National Joint Council for the Building Industry applicable to the Works and current at the date of tender.

(*b*) If the said rates of wages and other emoluments and expenses (including the cost of workmen's compensation insurance and Third Party Insurance) shall be increased or decreased by reason of any alteration in the said rules or decisions made after the said date of tender the net increase or decrease of such wages and other emolu-

ments and expenses shall be an addition to or a deduction from the Contract Sum as the case may be and be paid to or allowed by the Contractor accordingly.

(*c*) If by virtue of an instruction of the Uniformity Joint Board the Contractor is at the date of tender or shall become liable to comply with terms and conditions of the working rules of the Building and Civil Engineering Industries Uniformity Agreement 1940 or any amendment of that agreement, the net extra cost incurred by the Contractor through complying therewith, shall form an addition to the Contract Sum and shall be paid to the Contractor accordingly.

(*d*) If the site of the Works or the undertaking of the Contractor is at the date of tender or shall become scheduled under the Essential Work (Building and Civil Engineering) Orders 1941 and 1942 or any amendments thereof, any net extra cost incurred by the Contractor thereby shall form an addition to the Contract Sum and shall be paid to the Contractor accordingly.

(2) (*a*) The prices contained in the priced Bills of the materials and goods specified in the list attached to the Bills of Quantities are based on the market prices current at the date of tender (hereinafter referred to as " the basic prices ") and the Contractor shall state on the said list the basic prices of such materials and goods.

(*b*) If during the progress of the Works the market price of any of the materials or goods specified as aforesaid varies from the basic price thereof then the difference between the basic price and the market price payable by the Contractor and current when any such goods or materials are bought shall be a net addition to or a net deduction from the Contract Sum as the case may be and shall be paid to or allowed by the Contractor accordingly.

(3) (*a*) If the Contractor shall decide subject to clause 13 of these Conditions to sub-let any portion of the Works he shall incorporate in any sub-contract he enters into in respect of any portion of the Works so sub-let the provisions contained in sub-clauses (1) and (2) of this condition if and so far as the same may be relevant and applicable.

(*b*) If the price payable under a sub-contract which includes the provisions contained in sub-clauses (1) and (2) of this Condition is decreased below the price in such sub-contract by reason of the operation of the provisions of this clause then the net amount of such decrease shall be deducted from the Contract Sum and if the price payable under such a sub-contract shall be increased above the sub-contract price by reason of the operation of the provisions of this clause then the net amount of the increase shall be added to the Contract Sum.

The Contractor shall within a reasonable time give written notice to the Architect of the happening of any of the events referred to in paragraphs (*b*), (*c*), or (*d*) of sub-clause (1) of this Condition, of any increase or decrease

	Clause	
Period of Interim Certificates.	24 (*a*)	....
Period for Honouring of Certificates.	24 (*a*)	....
Percentage of Certified Value Retained (not to exceed 10 per cent.).	24 (*c*)	....
Limit of Retention Fund (half of which is to be released in accordance with clause 24 (*d*)).	24 (*c*)	....
Name and Branch of Bank.	24 (*d*) (A)	....

FORM OF SUB-CONTRACT

Issued under the sanction of the National Federation of Building Trades Employers and the National Federation of Specialists and Sub-Contractors, and recommended by the Royal Institute of British Architects for general use in conjunction with the R.I.B.A. form of Main Contract (1945) in cases where the Sub-Contractor is a nominated Sub-Contractor as defined by clause 21 (*a*) of that Form.

THIS SUB-CONTRACT (hereinafter referred to as "this Sub-Contract") dated the .... day of ...., 19 .... and made BETWEEN ....

....

of (or, whose Registered Office is situate at) ....

....

(hereinafter referred to as " the Contractor ") of the one part and......

....

of (or, whose Registered Office is situate at) ....

....

(hereinafter referred to as " the Sub-Contractor ") of the other part.

SUPPLEMENTAL to an Agreement (hereinafter referred to as " the Main Contract ") dated the .... day of ...., 19 .... and made between ....

....

(hereinafter referred to as " the Employer ") of the one part and the Contractor of the other part.

WHEREBY for the considerations herein appearing IT IS MUTUALLY AGREED AND DECLARED by and between the Contractor and Sub-Contractor as follows—that is to say :

(1) *Notice of the Main Contract to the Sub-Contractor.*—The Sub-Contractor having had a reasonable opportunity of inspecting the Main Contract or a copy thereof (except detailed prices in Schedules and Bills of Quantities) shall be deemed to have notice of all the provisions of the same (excepting as aforesaid).

(2) *Execution of the Sub-Contract Works.*—The Sub-Contractor shall execute and complete subject to and in accordance with this Sub-Contract the Works particulars of which are set out in Part I of the Schedule hereto (which Works form a part of the Works comprised in and to be executed in accordance with the Main Contract and are hereinafter referred to as " the Sub-Contract Works ") as altered or modified by any authorised variations omissions or instructions as hereinafter provided in all respects to the reasonable satisfaction of the Contractor and of the Architect for the time being under the Main Contract (hereinafter called " the Architect ") and in conformity with all the reasonable directions and requirements of the Contractor including all reasonable Rules of the Contractor (so far as they may apply) for the time being regulating the due carrying out of the Works under the Main Contract (hereinafter referred to as " the Main Contract Works ").

(3) *Sub-Contractor's Liability under Incorporated Provisions of the Main Contract.*—The Sub-Contractor agrees :

(*a*) To observe perform and comply with all the provisions of the Main Contract on the part of the Contractor to be observed performed and complied with so far as they relate and apply to the Sub-Contract Works (or any portion of the same) and are not repugnant to or inconsistent with the express provisions of this Sub-Contract as if all the same were severally set out herein ; and

(*b*) To indemnify and save harmless the Contractor against and from :

(i) any breach or non-observance or non-performance of the said provisions or any of them ; and

(ii) any act or omission of the Sub-Contractor his servants or agents which will or may involve the Contractor in any liability to the Employer under the Main Contract ; and

(iii) any damage loss or expense due to or resulting from any negligence or breach of duty on the part of the Sub-Contractor his servants or agents (inclusively of any wrongful user by him or them of the Contractor's property) ; and

(iv) any claim by an employee of the Sub-Contractor under the Workmen's Compensation Acts, Employers' Liability Acts, or other Acts of Parliament of a like nature respectively in force for the time being.

Provided that nothing in this Sub-Contract contained shall impose any liability on the Sub-Contractor in respect of any negligence or breach of duty on the part of the Contractor his sub-contractors his or their servants or agents.

(4) *Insurance by the Contractor of the Sub-Contract Works.*—(*a*) The Contractor shall for the benefit of himself and the Sub-Contractor at all material times insure and keep insured against loss or damage by fire the Sub-Contract Works in the full value thereof and the same (inclusively of any of the Sub-Contractor's materials properly on the site) shall as regards such loss or damage be at the sole risk of the Contractor.[1]

(*b*) In the event of any loss or damage by fire being caused to the Sub-Contract Works (inclusively of any of the Sub-Contractor's materials properly on the site) the Contractor to the extent of such loss or damage shall pay to the Sub-Contractor the full value of the same, such value to be calculated in accordance with clause 9 hereof.

(5) *Variations, etc., of the Sub-Contract Works.*—In the event of the Contractor

> (*a*) requiring or authorising in writing any variations of or omission from the Sub-Contract Works ; or
>
> (*b*) issuing in writing to the Sub-Contractor any instructions of the Architect in relation to the Sub-Contract Works (whether in regard to variations or otherwise howsoever) ;
>
> then the Sub-Contractor shall forthwith comply with and carry out the same in all respects accordingly.
>
> Save as aforesaid no variation of or omission from or other alteration or modification of the Sub-Contract Works shall be made or allowed by the Sub-Contractor.

(6) *Completion of the Sub-Contract Works.*—The Sub-Contractor after the signing of this Sub-Contract and within 7 days of the receipt by him of a written notice from the Contractor so to do shall with all reasonable dispatch proceed to execute and complete the Sub-Contract Works or the respective sections thereof within the period or respective periods specified in Part II of the said Schedule hereto.

PROVIDED that the Sub-Contractor shall pay to the Contractor any damage or loss suffered or incurred by the Contractor and caused by or

[1] *Note for information of users of the Form of Sub-Contract*

CLAUSE 4 (*a*) DAMAGE BY FIRE

If this Form is used in connection with the 1945 R.I.B.A. Form of Main Contract users should in their own interest ascertain whether alternative Clause 15 (*b*) of the Main Contract has been adopted. This alternative Clause provides that "The existing structures and the works . . . shall be at the sole risk of the Employer, as regards loss or damage by fire." If the Employer, that is the Building Owner, is not adequately covered by insurance and if he is not a man of substance there may be a risk of his becoming bankrupt following upon a fire on the Contract works. In this event the Principal Contractor would have to bear his own loss and would also be responsible under this Sub-Contract Form for the Sub-Contractor's loss. The Principal Contractor should, therefore, satisfy himself and his Sub-Contractors that where in the Principal Contract the alternative Clause 15 (*b*) is adopted the Building Owner is adequately covered by insurance.

due to the failure of the Sub-Contractor to complete within the said period or respective periods of which damage or loss as aforesaid the Contractor shall at the earliest opportunity give reasonable notice to the Sub-Contractor that the same is being or has been suffered or incurred unless such loss or damage shall be within the reasonable contemplation of the Sub-Contractor ; but so nevertheless that if such failure to complete as aforesaid

(*a*) shall be caused by or be due to any of the matters specified in Clause 5 (*a*) and (*b*) hereof or by or to any act or omission of the Contractor his sub-contractors, his or their respective servants or agents ; or

(*b*) shall be within any of the cases in which the Contractor could obtain an extension of the period or periods for completion under the Main Contract ;

then the Contractor shall grant a fair and reasonable extension of the said period or periods for completion of the Sub-Contract Works or the respective sections thereof (as the case may require) and such extended period or periods shall be the period or periods for completion of the same respectively and this clause shall be read and construed accordingly.

(7) *Defects.*—The Sub-Contractor shall, within a reasonable time after the receipt by him from the Contractor of the Architect's instructions or a copy thereof relating to the same, make good all defects shrinkages or other faults in the Sub-Contract Works which the Contractor (whether at his own costs or not) shall be liable to make good under the Main Contract.

PROVIDED that where the Contractor is liable to make good such defects shrinkages or other faults but not at his own costs then the Contractor shall secure a similar benefit to the Sub-Contractor and shall account to the Sub-Contractor for any money actually received by him in respect of the same.

(8) *Consequential Damage to the Contractor.*—If the Contractor (whether by himself or any sub-contractor) shall execute any work (of which before commencing the same the Contractor shall give reasonable notice to the Sub-Contractor) to the Main Contract Works (whether permanent or temporary) or any part of the same required by the Architect or rendered necessary or requisite by reason of defects shrinkages or other faults in the Sub-Contract Works then the Sub-Contractor shall pay to the Contractor the value of the execution of such work as aforesaid.

PROVIDED that if the Contractor shall pay or allow to the Employer the value of or other agreed sum (not exceeding such value as aforesaid) in respect of such work instead and in satisfaction of executing such work as aforesaid, then the Sub-Contractor shall pay to the Contractor such value or other agreed sum as aforesaid.

Similarly, if the Sub-Contractor shall execute any works (of which before commencing the same he shall give reasonable notice to the Contractor) to or in connection with the Sub-Contract Works (whether permanent or temporary) required by the Architect or rendered necessary

or requisite by reason of any defects shrinkages or other faults in the Main Contract Works then the Contractor shall pay to the Sub-Contractor the value of the execution of such work.

PROVIDED that if in stead and satisfaction of the Sub-Contractor actually executing such work as aforesaid, the Contractor shall pay or allow to the Employer the value of or other agreed sum (not exceeding such value) in respect of such work then the Contractor shall indemnify the Sub-Contractor against any damage or loss in respect of such value or other agreed sum as aforesaid.

(9) *Value of Sub-Contract Works.*—The value of the Sub-Contract Works shall be the price named in or determined by the provisions of Part III of the Said Schedule hereto, and the value of all extras, omissions, and variations shall be determined in accordance with the provisions of the Main Contract relating to authorised extras, omissions, or variations.

(10) *Contractor to Apply for Certificates of Payment.*—(*a*) The Contractor agrees subject to and in accordance with the Main Contract from time to time to make application (of which prior thereto the Contractor shall give to the Sub-Contractor reasonable notice) to the Architect for Certificates of payment and to include therein the amount that at the date thereof fairly represents the value of the Sub-Contract Works and of any extras, omissions, and variations authorised hereunder then executed and shall also embody therein or annex thereto any representations of the Sub-Contractor in regard to such value.

Interim Payments to the Sub-Contractor.—(*b*) Within 14 days of the receipt by the Contractor of such Certificate as aforesaid from the Architect and not before the receipt of such Certificate the Contractor shall pay to the Sub-Contractor the amount certified to be due in respect of the Sub-Contract Works and any authorised variations thereof

(i) less the due proportion of Retention money retained by the Employer ; and

(ii) (if payment is made within 14 days as aforesaid) less a cash discount of $2\frac{1}{2}$ per cent.

(*c*) PROVIDED that if the Sub-Contractor shall feel aggrieved by the amount so certified by the Architect or by his failure to certify, then subject

(i) to the provisions of the Arbitration Clause hereinafter contained ; and

(ii) to the Sub-Contractor giving to the Contractor such indemnity and security as the Contractor shall reasonably require ;

the Contractor shall allow the Sub-Contractor to use the Contractor's name in any arbitration proceedings by the Sub-Contractor in respect of the said matters complained of by the Sub-Contractor. (*See footnote A.*)

Footnote A.—Arbitration under this sub-clause would be governed by the provisions with regard to arbitration contained in the Main Contract. The sub-clause should be struck out when the Sub-Contractor is not nominated or selected by the Architect under the Main Contract. Nothing in this clause or elsewhere in the Sub-Contract creates any privity of contract between the Sub-Contractor and Employer.

(*d*) *Right of Sub-Contractor to suspend execution of Sub-Contract Works.*—If the Contractor shall fail to make any payment to the Sub-Contractor as hereinbefore provided, and such failure shall continue for 7 days after the Sub-Contractor shall have given the Contractor written notice of the same, then the Sub-Contractor may (but without prejudice to any other right or remedy) suspend the further execution of the Sub-Contract Works until such payment shall be made and in any case such period of suspension as aforesaid shall automatically operate as an extension of and be added to the time or times of completion (as the case may be) as hereinbefore provided and shall not be deemed a delay for which the Sub-Contractor is liable under this Sub-Contract. (*See footnote B.*)

(*e*) *Final Payment to the Sub-Contractor.*—PROVIDED that if before the issue of a Final Certificate to the Contractor under the Main Contract the Architect desires to secure final payment to the Sub-Contractor on completion of the Sub-Contract Works and shall (subject to the provisions of the Main Contract relating to prime cost and provisional sums) issue a Certificate to the Contractor including an amount to cover such final payment, then if

(i) the Sub-Contractor shall (subject to the Contractor's reasonable satisfaction) indemnify and secure the Contractor against all latent defects ; and

(ii) by such final payment the Contractor (subject to such latent defects) will be discharged under the Main Contract from all liabilities in respect of the Sub-Contract Works ;

the Contractor shall pay to the Sub-Contractor the amount so certified by the Architect as aforesaid.

Subject as aforesaid, the Contractor shall on the completion of the Main Contract Works and on the issue of the Certificate (if any) certifying the substantial completion of such works and of the Final Certificate under the Main Contract pay to the Sub-Contractor the respective due proportionate amounts attributable to the Sub-Contract Works and any authorised variations thereof with the proportionate accrued interest (if any), less a cash discount of $2\frac{1}{2}$ per cent. if payment is made within 14 days of the receipt by the Contractor of any such Certificate.

(11) *Sub-Contractor's Claim to Rights and Benefits under the Main Contract.*—The Contractor (so far as he lawfully can) will at the request and costs of the Sub-Contractor obtain for him any rights or benefits of the Main Contract so far as the same are applicable to the Sub-Contract Works but not further or otherwise.

(12) *Contractor's Right to Deduction or Set Off.*—The Contractor shall notwithstanding anything in this Sub-Contract contained be entitled to deduct from or set off against any monies due from him to the Sub-Contractor (inclusively of any Retention monies) any sum or sums for

Footnote B.—Sub-Contractors should note that under the Main Contract in certain events the Employer may have the power to pay them direct.

which the Sub-Contractor is liable to the Contractor under this Sub-Contract, whether for damages or otherwise.

(13) *Right of Access of Contractor and Architect.*—The Contractor and the Architect (and all persons duly authorised by them or either of them) shall at all reasonable times have access to any work which is being prepared for or will be utilised in the Sub-Contract Works unless the Architect shall certify in writing that the Sub-Contractor has reasonable grounds for refusing such access.

(14) *Sub-letting of Sub-Contract Works.*—The Sub-Contractor shall not sub-let the Sub-Contract Works or any portion of the same without the written consent of the Contractor and the Architect such consent by the Contractor not to be arbitrarily or unreasonably withheld, and in case of any difference of opinion between the Contractor and the Architect, the opinion of the Architect shall prevail.

(15) *Provision of Water, etc., for Sub-Contract Works.*—If and so far as provided in the Main Contract (but not otherwise) the Contractor shall supply at his own costs all necessary water lighting watching and attendance for the purposes of the Sub-Contract Works.

Subject as aforesaid the Sub-Contractor shall make all necessary provision in regard to the said matters and each of them.

(16) *Sub-Contractor's User of Scaffolding of Contractor.*—The Sub-Contractor his employees and workmen shall for the purposes of the Sub-Contract Works (but not further or otherwise) be entitled in common with all other persons having the like right to use the scaffolding (if any) the property of and remaining for the time being erected by the Contractor.

Provided that such user as aforesaid shall be on the express condition, *viz.*:

> (1) That no warranty or other liability on the part of the Contractor or of his sub-contractors shall be created or implied in regard to the fitness condition or suitability of the said scaffolding; and
>
> (2) The Sub-contractor shall be solely liable for all claims for damages or otherwise in respect of accidents in connection with such scaffolding so used by the Sub-Contractor or his employees or workmen or otherwise arising out of and caused by such user and the Sub-Contractor hereby agrees to indemnify the Contractor and any sub-contractor of his against all such claims and any legal or other proceedings in respect of the same and against all costs charges and expenses of the same or any of the same.

(17) *Contractor and Sub-Contractor not to make Wrongful User of or Interference with the Property of the Other.*—Save as hereinbefore expressly provided the Contractor and the Sub-Contractor respectively their respective servants or agents shall not make any wrongful user of or interfere with the plant ways scaffolding temporary works appliances or other property respectively belonging to the other of them or be guilty of any act or omission which shall constitute a breach or infringement of any Act of Parliament or of any legally binding by-law regulation order or

rule made under the same or by any local or other public or competent authority.

PROVIDED that nothing herein contained shall prejudice or limit the rights of the Contractor or the Sub-Contractor in the carrying out of their respective statutory duties or contractual duties hereunder or under the Main Contract.

(18) *Temporary Workshops, etc.*—Save as otherwise provided in the Main Contract the Sub-Contractor at his own expense shall provide and erect all necessary workshops sheds or other buildings for his employees and workmen at such places on the site as the Contractor shall appoint and the Contractor agrees to give all reasonable facilities to the Sub-Contractor for such erection.

(19) *Plant, Tools, etc., of Sub-Contractor to be at his Sole Risk.*—The plant tools equipment or other property of the Sub-Contractor his servants or agents (other than materials properly on the site) shall be at the sole risk of the Sub-Contractor, and any loss or damage to the same shall be the sole liability of the Sub-Contractor who hereby agrees to indemnify the Contractor against such loss or damage or any claim or proceedings in respect thereof and the costs charges and expenses of the same or any of the same and any insurance against any of the foregoing matters shall be the sole concern of the Sub-Contractor.

(20) *Insurance by the Contractor and the Sub-Contractor Respectively.*—The Contractor and Sub-Contractor respectively shall so far as is reasonably practicable effect (and keep on foot) during all material times Policies of Insurance with such Insurance Company or other insurers and of such an amount as shall be approved by the other against their respective liabilities under the Fatal Accidents Act, 1846, The Employers' Liability Act, 1880, and any Workmen's Compensation Acts and any Acts replacing and/or amending the same or any of the same as may be in force at the time, and at Common Law in respect of injuries to persons or property arising out of and in the course of the execution of the Main Contract works and the Sub-Contract Works and/or arising out of and in the course of the employment of any workmen employed by them respectively or caused thereby or due thereto respectively and each respectively shall at all reasonable times on the request of the other produce for his inspection the policy or policies of insurance and the receipts for the premiums paid.

(21) *Determination of this Sub-Contract by the Contractor.*—(*a*) If the Sub-Contractor shall make default in any of the following respects, *viz.* :

(i) without reasonable cause wholly suspend the Sub-Contract Works before completion ;

(ii) fail to proceed with the Sub-Contract Works with reasonable diligence ;

(iii) refuse or to a substantial degree persistently neglect after notice in writing from the Contractor to remove defective work or improper material ;

then if such default shall continue for 10 days after written and registered

notice to the Sub-Contractor from the Contractor specifying the same the Contractor may (without prejudice to any other rights or remedies) thereupon by written and registered notice determine this Sub-Contract; provided that notice hereunder shall not be given unreasonably or vexatiously and such notice shall be void if the Contractor is at the time of the notice in breach of his Sub-Contract; or

(*b*) If the Sub-Contractor shall commit any act of bankruptcy or make or enter into any deed of arrangement or composition with his creditors or suffer or allow any execution, whether legal or equitable, to be levied on his property or obtained against him, then the Contractor may (without prejudice to any other rights or remedies) by written notice forthwith determine this Sub-Contract.

(*c*) *Rights and Liabilities of the Parties* inter se *on such Determination.*—In case of this Sub-Contract being determined under (*a*) or (*b*) of this clause, then the Sub-Contractor shall be deemed to be in breach of this Sub-Contract and the Contractor shall only be liable for the value of any work actually and properly executed and not paid for at the date of such determination, such value to be calculated in accordance with Clause 9 hereof and for no other sum or sums whatsoever and shall have the right to recover, or to deduct from or set off against any such amount, the amount of damage suffered and/or of loss and expense incurred by the Contractor by reason of the determination of this Sub-Contract under this clause.

(22) *Construction of this Sub-Contract in relation to the Main Contract.*—Nothing in this Sub-Contract contained shall be deemed to limit or prejudice the right of the Contractor to determine the Main Contract subject to and in accordance with the terms of the same or to limit or prejudice the right of the Contractor (save as in this Sub-Contract expressly provided) to execute and carry out the Main Contract Works in accordance with its terms and the exercise of any such rights or of such right of determination by the Contractor as aforesaid shall not be or be deemed to be a breach by the Contractor of this Sub-Contract and in the event of the Contractor determining the Main Contract as aforesaid then this Sub-Contract shall thereupon also determine without any right or claim on the part of the Sub-Contractor to damages or for loss or expense or otherwise but the Sub-Contractor shall be entitled to be paid by the Contractor the value of the Sub-Contract Works and any authorised variations thereof actually executed by the Sub-Contractor and not paid for at the date of such determination, such value to be calculated in accordance with Clause 9 hereof.

Save as aforesaid in the event of the provisions of the Main Contract (so far as they are applicable to the Sub-Contract Works) being repugnant to or inconsistent with this Sub-Contract the provisions of this Sub-Contract shall prevail and this Sub-Contract shall be read and construed accordingly.

(23) *Wages and Conditions.*—(*a*) Provided always and this Sub-Contract

is upon this express condition that during its continuance the wages and conditions of employment of the employees and workmen of the Contractor and Sub-Contractor respectively engaged on the Main Contract Works and the Sub-Contract Works shall be such as may from time to time be prescribed by the competent authority in the industry or trade to which such employees or workmen belong and the Contractor and Sub-Contractor hereby mutually agree respectively to pay and observe the same accordingly.

PROVIDED that in default of such wages and/or conditions of employment being prescribed as aforesaid the Contractor and Sub-Contractor as a condition of this Sub-Contract shall pay such wages and/or observe such conditions of employment as may be generally from time to time prevailing in industries or trades of a similar or comparable nature in the districts in which their said respective employees and workmen are engaged.

(*b*) If either party shall commit a breach of this Clause, then the other party shall be entitled (without prejudice to any other right or remedy) to be indemnified by the party so in breach against any loss or damage accruing from or arising out of or connected with such breach.

(24) *Arbitration.*—In the event of any dispute or difference between the Contractor and Sub-Contractor whether arising during the execution or after the completion of the Sub-Contract Works or after the determination of this Sub-Contract, whether by breach or in any other manner, in regard to :

(*a*) the construction of this Sub-Contract ; and/or

(*b*) the respective rights and liabilities of the parties hereto thereunder ; and/or

(*c*) any matter or thing arising out of or in relation to or in connection with this Sub-Contract and/or the execution of the Sub-Contract Works ;

then either party shall give to the other written notice of the same and such dispute or difference shall be and hereby is referred to the arbitration of such person as the parties hereto may agree upon and failing such agreement then in accordance with the Arbitration Acts, 1889–1934, and any Acts amending the same (save as in this Clause provided) of such single arbitrator as may be appointed on the request of either party by the President for the time being of the Chartered Surveyors' Institution and the Award of such Arbitrators shall be final and binding on the parties.

PROVIDED that such Arbitrator shall not without the written consent of the Architect or Contractor enter on the arbitration until after the completion of the Main Contract Works.

AND PROVIDING FURTHER that in any such arbitration as is provided for in this clause, any decision of the Architect which is final and binding on the Contractor under the Main Contract shall also be and be deemed to be final and binding between and upon the Contractor and the Sub-Contractor.

IN WITNESS WHEREOF the parties hereto have set their hands (or, the Common Seal of the parties hereto has been affixed or the Common Seal of the Contractor has been affixed and the Sub-Contractor has set his hand hereto, or the Contractor has set his hand and the Common Seal of the Sub-Contractor has been affixed hereto) the day and year first above written. (*See footnote.*)

Note for information of users of the Form of Sub-Contract

EXECUTION AND ATTESTATION UNDER HAND

If the seal of a Company is affixed to this Agreement a ten-shilling stamp will have to be impressed ; otherwise it should bear a sixpenny stamp.

The following are the appropriate forms of execution by an Individual, by a Partner in a firm, and by a Director of a company :

FOR AN INDIVIDUAL

Signed by the said

....

in the presence of

Name ....

Address ....

Description ....

FOR A FIRM

Signed by ....

Partner in the firm of ....

....

in the presence of

Name ....

Address ....

Description ....

FOR A COMPANY

Signed by ....

Director of

.... *Limited*

in the presence of

Name ....

Address ....

Description ....

For and on behalf of

Limited

Signature of the Contractor ....

Signature of the Sub-Contractor ....

Signed by the above-named Contractor in the presence of

Name ....

Address ....

Occupation ....

Signed by the above-named Sub-Contractor in the presence of

Name ....

Address ....

Occupation ....

or,

COMMON SEAL of the above-named Contractor

Common Seal of the above-named Contractor affixed in the presence of

Director ....

Director ....

and

Secretary ....

COMMON SEAL of the above-named Sub-Contractor

Common Seal of the above-named Sub-Contractor affixed in the presence of

Director ....

Director ....

and

Secretary ....

....

....

....

....

SCHEDULE ABOVE REFERRED TO

Part I

Clause 2 of this Sub-Contract.

Particulars of the works (being a part of the Works comprised in the Main Contract) in this Sub-Contract referred to as " the Sub-Contract Works," viz. :

....

....

....

....

Part II

Clause 6.

Description of work.	Completion period or periods of the Sub-Contract Works or respective sections thereof.
....	....
....	....
....	....
....	....

Part III

Clause 10

Value of the Sub-Contract Works

....

....

....

.... £ : :

CHAPTER 13

USEFUL DATA

I. STANDARD WEIGHTS AND MEASURES

ENGLISH STANDARD WEIGHTS AND MEASURES
LINEAL MEASURE OR LENGTH

1 nail equals $2\frac{1}{4}$ inches
1 hand equals 4 inches
3 inches equal 1 palm
7·42 inches equal 1 link
9 inches equal 1 span or $\frac{1}{4}$ yard
12 inches equal 1 foot
3 feet or 4 quarters equal 1 yard
5 quarters of yard equal 1 ell
6 feet or 2 yards equal 1 fathom
16 feet 6 inches, or $5\frac{1}{2}$ yards, or 25 links, equal 1 rod, pole, or perch
4 poles or 22 yards equal 1 chain
$5\frac{1}{2}$ yards equal 25 links, 1 pole, rod, or perch
220 yards equal 1 furlong
1,760 yards or 8 furlongs equal 1 mile or 5,280 feet
100 links or 66 feet equal 1 chain
10 chains equal 1 furlong
8 furlongs, or 80 chains, or 1,760 yards, or 5,280 feet, equal 1 mile
3 miles equal 1 league

Useful equivalents : a halfpenny measures 1 inch ; a penny $1\frac{1}{4}$ inches ; a sixpence $\frac{3}{4}$ inch ; a shilling $\frac{7}{8}$ inch ; a florin $1\frac{1}{8}$ inches ; half a crown $1\frac{1}{4}$ inches.

Signs.—The inch is indicated by in. or ″ ; the foot by f., ft., or ′ ; the yard by y. or yd. ; the mile by m. ; the link by l. ; the rod by rd. ; the chain by ch.

SURFACE OR SQUARE MEASURE

144 square inches equal 1 square foot
9 square feet equal 1 square yard
100 square feet equal 1 square (of roofing, boarding, flooring)
$272\frac{1}{4}$ square feet, or $30\frac{1}{4}$ square yards, or 625 square links, equal 1 square rod, pole, or perch
16 square rods equal 1 square chain
40 square rods equal 1 rood

4 roods, or 4,840 square yards, or 43,560 square feet, equal 1 acre
62·7264 square inches equal 1 square link
10,000 square links equal 1 square chain
10 square chains equal 1 acre
100 acres equal 1 hide
640 acres equal 1 square mile

Signs.—Square inch is represented by s.i. or sq. in.; square feet by s.f. or sq. ft.; square yard by s.y. or sq. yd.; square rod by sq. rd.; square chain by sq. ch.; acre by a. or ac.; square mile by sq. m.

A square on plan has equal sides; a square inch, therefore, is 1 inch long × 1 inch wide; 12 inches × 12 inches equal 1 square foot or 144 square inches. To ascertain the area of a parallelogram, which is a rectangle longer than it is broad, multiply the length by the width. To ascertain the area of an irregular figure or space, divide the figure into a number of parallel strips of equal width, then if AB is the first strip and YZ the last, add these lengths together and divide by 2, add the result to the length of the other successive strips and multiply the total by the width between the two strips. Thus:

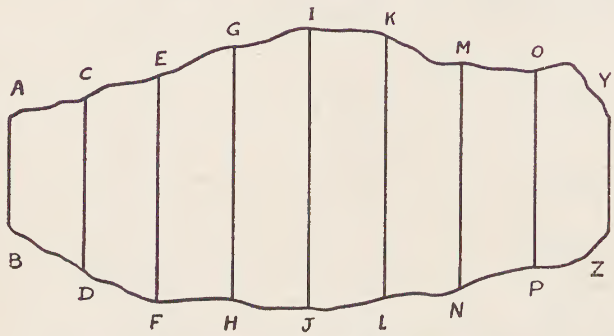


Fig. 144.—Measuring area of irregular figure.

$$\left(\frac{AB + YZ}{2} + CD + EF + GH, \text{etc.}\right)\frac{l}{n}$$

where l equals length of figure perpendicular to strips (that is to say, the distance between AB and YZ) and n equals the number of strips.

The area of a triangle is obtained by multiplying half the length of the base by the perpendicular height. To ascertain the surface area of walls measure their length and multiply by height, then deduct area of windows, doors, and fireplace, if needed (for instance if the walls are to be plastered, painted, or papered). For a circular, or oval, room, take the circumference and multiply by height. A ready way to ascertain the area of a ceiling is to square the floor space (multiply length by breadth), and if necessary make an allowance by deducting for cornice.

The surface or square measure is also known as the super or superficial measure, hence feet super or yard super.

CUBIC OR SOLID MEASURE

1,728 cubic inches equal 1 cubic foot
27 cubic feet equal 1 cubic yard

Signs.—Cubic inch is represented by cu. in.; cubic foot by cu. ft.; cubic yard by cu. yd.

A true cube has equal breadth, length, and height; therefore, to ascertain the cubic content of any figure multiply breadth by length and the result by the height. Thus, to obtain the cubic content of a rectangular room, tank, etc., square the base (that is, multiply the length by the length) and multiply the result by the height. If the room, or vessel, is circular, proceed by either one of the following methods: (1) multiply the radius (half the diameter) by itself, the result by the standard figure 3·141, and the result by the height; (2) multiply the diameter by the diameter, the result by the standard figure 0·785, and the result by the height. If the room, or vessel, is elliptical, multiply the product of the two axes by the standard figure 0·7854 and the result by the height; (3) $\frac{D \times d \times \pi}{4}$, where D = large diameter; d = small diameter; $\pi = 3{\cdot}1416$.

DENSITY, SPECIFIC HEAT, CO-EFFICIENT OF EXPANSION AND MELTING-POINTS

	Specific gravity.	Density pounds per cu. foot.	Specific heat.	Co-efficient of expansion per ° F.	Melting-point, ° F., 32°
Water at 32° F.	1	62·42	1	—	—
Aluminium	2·6	161·7	·212	.000034	1,157
Brass	8·1	503	·094	·000031	1,650
Copper	8·79	545	·092	·000031	1,929
Glass	2·89	180·7	·198	·000013	2,007
Ice at 32° F.	·92	57·5	·504	—	—
Iron (cast)	7·5	465	·130	·000018	1,960
Iron (wrought)	7·74	582	·114	·000022	2,912
Lead	11·35	708	·031	·000048	618
Limestone	3·16	197	·217	—	—
Masonry and cement	2·24	140	·2	·000023	—
Nickel	8·9	547	·109	·000020	2,642
Oak	·86	54	·57	—	—
Platinum	21·5	134·2	·032	·000015	3,227
Pine (white)	·55	34·6	·65	—	—
Steel	7·83	486	·116	·000020	2,790
Tin	7·29	452	·056	·000035	446
Zinc	7·19	445	·095	·000049	776

Specific heat water is taken as unity and the figures are based on the number of B.Th.U. required to raise 1 pound of the substance through 1° F.

CUBING A BUILDING FOR APPROXIMATE ESTIMATE

Multiply length by breadth (overall) and the product by height from bottom of foundation to halfway up the roof.

When there are attics in the roof, an allowance of three-quarters up the roof, instead of halfway up is made.

In case of flat roofs the height is measured from bottom of the foundations to top of parapet or 2 ft. above roof, whichever is greater.

AVOIRDUPOIS WEIGHT

27·344 grains equal 1 drachm or dram
16 drams equal $437\frac{1}{2}$ grains or 1 ounce
16 ounces equal 7,000 grains or 1 pound
14 pounds equal 1 stone
28 pounds equal 1 quarter
4 quarters equal 112 pounds, or 1 hundredweight
20 hundredweights equal 2,240 pounds, or 1 ton
3 pennies, or 5 halfpennies, when new, weigh 1 ounce

Abbreviations.—Gr., grain ; dr., dram ; oz., ounce ; lb., pound ; cwt., hundredweight ; t., ton.

Note.—Three pennies, or five halfpennies, or ten farthings, or five shillings, or ten sixpenny pieces weigh 1 ounce.

LIQUID MEASURES

8·665 cu. inches equal 1 gill
4 gills equal 1 pint
2 pints equal 1 quart
4 quarts equal 1 gallon
1 gallon equals $277\frac{3}{4}$ cu. inches, or 0·16 cu. feet, or 10 pounds of distilled water
1 cu. foot equals 6·232 gallons
1 cwt. of water equals 1·8 cu. feet
1 bushel equals 1·28 cu. feet
8 gallons equal 1 bushel

CIRCULAR MEASURES

60 seconds ″ equal 1 minute ′
60 minutes equal 1 degree °
90 degrees equal 1 right-angle rt.
360 degrees equal 1 circle ○
1 degree equals 60′, or 3,600 ″

A quadrant is $\frac{1}{4}$ of a circle, or 90° ; a sextant is $\frac{1}{6}$ of a circle, or 60°. The unit is the degree, or $\frac{1}{360}$ of the circumference of a circle. The circumference is the perimeter or periphery of the circle ; the diameter is its width, and the radius half the diameter.

MISCELLANEOUS MEASURES

12 articles equal 1 dozen ; 12 dozen, 1 gross ; 12 gross, 1 great gross ; 20 articles, 1 score.

SIGNS IN CALCULATIONS

A common fraction is used to represent a division of some unit, and is composed of a numerator (a figure above a horizontal bar or to the left of a diagonal bar) and a denominator (a figure below a horizontal, or to the right of a diagonal bar). When we have several denominators which are multiples of each other we have a common denominator, thus, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, or $\frac{1}{7}$, $\frac{1}{14}$, $\frac{1}{28}$, have a common denominator for each of the groups, 32 and 28 respectively. In practice the fractions, when possible, are reduced to the lowest denominator; thus, $\frac{2}{8}$ would become $\frac{1}{4}$, or $\frac{4}{16}$, $\frac{1}{4}$. If we add together $\frac{7}{8}$, $\frac{7}{8}$, and $\frac{1}{8}$, we obtain $\frac{15}{8}$; this is an improper fraction, which when reduced becomes $1\frac{7}{8}$. A decimal fraction is represented by a dot before a figure, thus ·1, which means division by a tenth, so that ·1 is equal to $\frac{1}{10}$. ·01 to $\frac{1}{100}$, and so on.

$+$, the plus sign, indicates addition; thus, $1 + 2$ is 3.
$-$, the minus sign, indicates subtraction; thus, $2 - 1$ is 1.
$\times$, the multiplication sign, indicates multiplication; thus, 2×3 is 6.
$\div$, the division sign, indicates division; thus, $4 \div 2$ is 2.
$=$ is the equality sign; thus, 12 inches equal 1 foot; or $\frac{3}{8} + \frac{1}{8} = \frac{1}{2}$.

An exponent is a small figure, written alone and to the right of another figure, and signifies that its value must be raised. Thus 2^2 means that the figure must be squared; thus: $2 \times 2 = 4$. If we have 2^3, it must be cubed; thus: $2 \times 2 \times 2 = 8$.

Parentheses ( ), brackets [ ], and braces { }, generally all referred to as brackets, when used in calculations denote that the operations within the brackets have to be performed first, and if more than one pair are used, then the inner one is taken first. Thus $2(3 - 1)$, the subtraction is made before multiplying by 2; in this case we have 3 less $1 = 2$, $\times\ 2 = 4$. Or, $2[2 + (4 - 3)]$, we deduct 3 from 4 leaving 1, which is added to 2 and multiplied by $2 = 6$.

The minus sign when raised $^{-}$ is called the vinculum, and has the same value as a bracket, but is more generally used in connection with the radical sign $\sqrt{\ }$, which means that the square root of the figure under the vinculum has to be ascertained; thus $\sqrt{16} = 4$. If the radical contains a small 3, thus $\sqrt[3]{\ }$, the cube root has to be found; thus $\sqrt[3]{27} = 3$. If the figure is four, the fourth root has to be found.

The Greek letter pi π means the ratio between the circumference of a circle and the diameter, which has a constant value of 3·1416.

The signs : : : : indicate proportion; thus 3 : 4 : : 6 : 8 should be read 3 is to 4 as 6 is to 8. The proportion sign : is also used in another way. For instance, a concrete mix of cement, sand, and coarse aggregate indicated thus: 1 : 2 : 3, would mean 1 part by volume of cement to 2 parts of sand and 3 parts of aggregate.

DECIMAL EQUIVALENTS TO FRACTIONS OF AN INCH

$\frac{1}{64}$	·015625	$\frac{17}{64}$	·268625	$\frac{33}{64}$	·515625	$\frac{49}{64}$	·765625
$\frac{1}{32}$	·031250	$\frac{9}{32}$	·281250	$\frac{17}{32}$	·531250	$\frac{25}{32}$	·781250
$\frac{3}{64}$	·046875	$\frac{19}{64}$	·296875	$\frac{35}{64}$	·546875	$\frac{51}{64}$	·796875
$\frac{1}{16}$	·062500	$\frac{5}{16}$	·312500	$\frac{9}{16}$	·562500	$\frac{13}{16}$	·812500
$\frac{5}{64}$	0·78125	$\frac{21}{64}$	·328125	$\frac{37}{64}$	·578125	$\frac{53}{64}$	·828125
$\frac{3}{32}$	·093750	$\frac{11}{32}$	·343750	$\frac{19}{32}$	·593750	$\frac{27}{32}$	·843750
$\frac{7}{64}$	·109375	$\frac{23}{64}$	·359375	$\frac{39}{64}$	·609375	$\frac{55}{64}$	·859375
$\frac{1}{8}$	·125000	$\frac{3}{8}$	·375000	$\frac{5}{8}$	·625000	$\frac{7}{8}$	·875000
$\frac{9}{64}$	·140625	$\frac{25}{64}$	·390625	$\frac{41}{64}$	·640625	$\frac{57}{64}$	·890625
$\frac{5}{32}$	·156250	$\frac{13}{32}$	·406250	$\frac{21}{32}$	·656250	$\frac{29}{32}$	·906250
$\frac{11}{64}$	·171875	$\frac{27}{64}$	·421875	$\frac{43}{64}$	·671875	$\frac{59}{64}$	·921875
$\frac{3}{16}$	·187500	$\frac{7}{16}$	·437500	$\frac{11}{16}$	·687500	$\frac{15}{16}$	·937500
$\frac{13}{64}$	·203125	$\frac{29}{64}$	·453125	$\frac{45}{64}$	·703125	$\frac{61}{64}$	·953125
$\frac{7}{32}$	·218750	$\frac{15}{32}$	·468750	$\frac{23}{32}$	·718750	$\frac{31}{32}$	·968750
$\frac{15}{64}$	·234375	$\frac{31}{64}$	·484375	$\frac{47}{64}$	·734375	$\frac{63}{64}$	·984375
$\frac{1}{4}$	·250000	$\frac{1}{2}$	·500000	$\frac{3}{4}$	·750000	1	1

AREA OF CIRCLES AND SQUARES

Diameter of circle in inches.	Area of circle in sq. inches.	Sides of square of same area in sq. inches.	Diameter of circle in inches.	Area of circle in sq. inches.	Sides of square of same area in sq. inches.
1	·785	·89	6	28·274	5·32
$1\frac{1}{2}$	1·767	1·33	$6\frac{1}{2}$	33·483	5·76
2	3·142	1·77	7	38·485	6·20
$2\frac{1}{2}$	4·709	2·22	$7\frac{1}{2}$	44·179	6·65
3	7·069	2·66	8	50·266	7·09
$3\frac{1}{2}$	9·621	3·10	$8\frac{1}{2}$	56·745	7·53
4	12·566	3·54	9	63·617	7·98
$4\frac{1}{2}$	15·635	3·99	$9\frac{1}{2}$	70·032	8·42
5	19·635	4·43	10	78·540	8·86
$5\frac{1}{2}$	23·758	4·87			

METRIC MEASURES

The metric system is based on multiples and divisions of ten.

Linear Measure

10 millimetres (mm.) equal 1 centimetre (cm.) or ·3937 inch.
10 centimetres equal 1 decimetre (dm.) or 3·937 inch.
10 decimetres equal 1 metre (m.) or 3·281 feet.
10 metres equal 1 decametre (Dm.) or 32·81 feet.
10 decametres equal 1 hectametre (Hm.) or 328·09 feet.
10 hectametres equal 1 kilometre (Km.) or 0·6213 mile.

Square Measure

100 sq. millimetres (sq. mm., or mm.^2) equal 1 sq. centimetre (sq. cm. or cm.^2).
100 sq. centimetres equal 1 sq. decimetre (sq. dm. or dm.^2).
100 square decimetres equal 1 sq. metre or 1 centiare (ca.).
100 sq metres equal 1 sq. decametre (sq. dm. or dm.^2) or 1 are.
100 square decametres equal 1 hectare (Ha).

Cubic Measure

1,000 cu. millimetres (cu. mm. or mm.^{3}) equal 1 cu. centimetre (cu. cm. or cm.^{3}).
1,000 cu. centimetres equal 1 cu. decimetre (dm.^{3}).
1,000 cu. decimetres equal 1 cu. metre (m.^{3}).
1 litre contains 10 decalitres, or 100 centilitres, or 1,000 millilitres.

METRIC CONVERSION FACTORS

To convert millimetres into inches divide by 25·4 ; or
To convert millimetres into inches multiply by ·03937.
To convert centimetres into inches divide by 2·54 ; or
To convert centimetres into inches multiply by ·3937.
To convert metres into inches multiply by 39·37
To convert metres into feet multiply by 3·281.
To convert kilometres into miles multiply by ·62137 ; or
To convert kilometres into miles divide by 1·6093.
To convert sq. millimetres into sq. inches multiply by ·00155.
To convert sq. centimetres into sq. inches multiply by ·155.
To convert sq. metres into sq. feet multiply by 10·764.
To convert sq. kilometres into acres multiply by 247·1.
To convert cu. centimetres into cu. inches multiply by 16·383.
To convert cu. metres into cu. feet multiply by 35·3145.
To convert sq. metres into cu. yards multiply by 1·308.
To convert sq. metres into gallons multiply by 220.
To convert litres into gallons multiply by ·22.
To convert litres into pints multiply by 1·76.
To convert litres into cu. inches multiply by 61·025385.
To convert grammes into grains multiply by 15·4323.
To convert grammes into ounces multiply by ·03527.
To convert kilogrammes into pounds multiply by 2·2046.

MILLIMETRES INTO DECIMALS OF AN INCH

Millimetres.	0	1	2	3	4	5	6	7	8	9
0	0	·0394	·0787	·1181	·1575	·1969	·2362	·2756	·3150	·3543
10	·3937	·4331	·4724	·5118	·5512	·5906	·6299	·6693	·7087	·7480
20	·7874	·8268	·8661	·9055	·9449	·9843	1·0236	1·0630	1·1024	1·1417
30	1·1811	1·2205	1·2598	1·2992	1·3386	1·3780	1·4173	1·4567	1·4961	1·5354
40	1·5748	1·6142	1·6535	1·6929	1·7323	1·7717	1·8110	1·8504	1·8898	1·7291
50	1·9685	2·0079	2·0472	2·0866	2·1260	2·1654	2·2047	2·2441	2·2835	2·3228
60	2·3622	2·4016	2·4409	2·4803	2·5197	2·5591	2·5984	2·6378	2·6772	2·7165
70	2·7559	2·7953	2·8346	2·8740	2·9134	2·9528	2·9921	3·0315	3·0709	3·1102
80	3·1496	3·1890	3·2283	3·2677	3·3071	3·3465	3·3858	3·4252	3·4646	3·5039
90	3·5433	3·5827	3·6220	3·6614	3·7008	3·7402	3·7795	3·8189	3·8583	3·8976

LINKS INTO FEET AND FEET INTO LINKS

Links.	Feet.	Feet.	Links.
1	·66	1	1·5151
2	1·32	2	3·0303
3	1·98	3	4·5454
4	2·64	4	6·0606
5	3·3	5	7·5757
6	3·96	6	9·0909
7	4·62	7	12·1212
8	5·28	8	10·6060
9	5·94	9	13·6363
10	6·6	10	15·1515
20	13·2	20	30·30
30	19·8	30	45·45
40	26·4	40	60·61
50	33·0	50	75·75
60	39·6	60	90·91
70	46·2	70	106·06
80	52·8	80	121·21
90	59·4	90	136·36
100	66·0	100	151·51

CUSTOMARY MEASURES

A bag, or sack, of plaster (London measure) equals 14 pounds equal 1 bushel.

A bag, or sack, of Portland cement equals 2 centals equal 200 pounds equal 2 bushels.

A bag, or sack, of lime equals 186 pounds equal 3 bushels.

A bundle of laths equals about 125 laths equal 360–500-foot run.

A load of bricks equals 500.

A load of earth or ballast equals 1 cu. yard.

A load of lime equals 32 bushels.

A pig of ballast equals 56 lb.

A rod of brickwork equals $16\frac{1}{2}$ feet square of $1\frac{1}{2}$ bricks, or 272 sup. feet equals 306 cu. feet.

A sack, *see* bag.

A square equals 100 sq. feet.

A seam of glass equals 120 pounds

A faggot, or fodder, of lead (London) equals 2,184 pounds.

A faggot, or fodder, of steel equals 120 pounds.

A long hundredweight equals 112 pounds.

A short hundredweight equals 100 pounds.

A long ton equals 2,240 pounds.

A short ton equals 2,000 pounds.

1,000 of slates equal 1,200.

100 deals equal 120.

1 stone equals 14 pounds.

II. *EXCAVATIONS AND DRAINAGE*

EXCAVATION PER HOUR

Labour.	Cu. yards per hour
Shovelling building rubbish, loose soil, sand (no digging)	$2\frac{1}{2}$
Digging garden soil or made ground and throwing out	$1\frac{1}{4}$–$1\frac{1}{2}$
Digging in loamy soil and throwing out	$1\frac{1}{2}$–$1\frac{3}{4}$
Digging in stiff clay and throwing out	$\frac{1}{2}$–$\frac{3}{4}$
Digging in chalk and throwing out	$\frac{1}{2}$
Digging in hard ground (including picking) and throwing out	$\frac{1}{4}$–$\frac{1}{2}$
Above are for single throws of not more than 6 feet; each additional throw increase by $1\frac{1}{2}$–3 cu. yards.	
Filling in barrows or baskets	$3\frac{1}{2}$
Filling in carts	2–$2\frac{1}{2}$
Each run (run = 20 yards)	3
Returning or filling, without ramming	2
Ramming	2
Levelling ground, no throwing	6

MEASURING EXCAVATIONS

When digging not over 12 inches deep per yard super; over 12 inches deep per yard cube, stating each 6 feet depth separate. If carted away state number of runs (1 run = 20 yards). Planking and strutting per foot super.

ESTIMATED WEIGHT OF EXCAVATED MATERIALS

To ascertain weight of material excavated, or to be excavated, cube the mass and divide by the specific weight of the material.

In order to simplify the process a chart was designed by a Canadian civil engineer (see Fig. 145).

To use the chart, cube the mass and ascertain the nature of the material. Lay a straightedge across the chart to the appropriate degrees on the columns A or B to the appropriate mark in column D, and the weight will be found at the intersection in column C. This column is calculated on standard characteristics, but as the nature of soils vary greatly (loose gravel from 90 pounds to 105 pounds per cu. foot; dry sand from 100 pounds to 120 pounds, rubble from 80 pounds to 110 pounds, and so on), it may be necessary to test the materials prevalent in any locality, or on the particular job, and adjust the middle column accordingly. In new-"made" or patchy soils it is best to take a mean of three weighed examples.

DEPTH OF VERTICAL FACE OF EXCAVATIONS WHICH WILL STAND FOR SHORT PERIODS

Type of soil.	Depth in feet.
Clean, dry sand and gravel	0–1
Moist sand and ordinary surface mould	1–3
Loamy soil, well drained	5–10
Clay, well drained	9–12
Compact gravelly soil	10–15

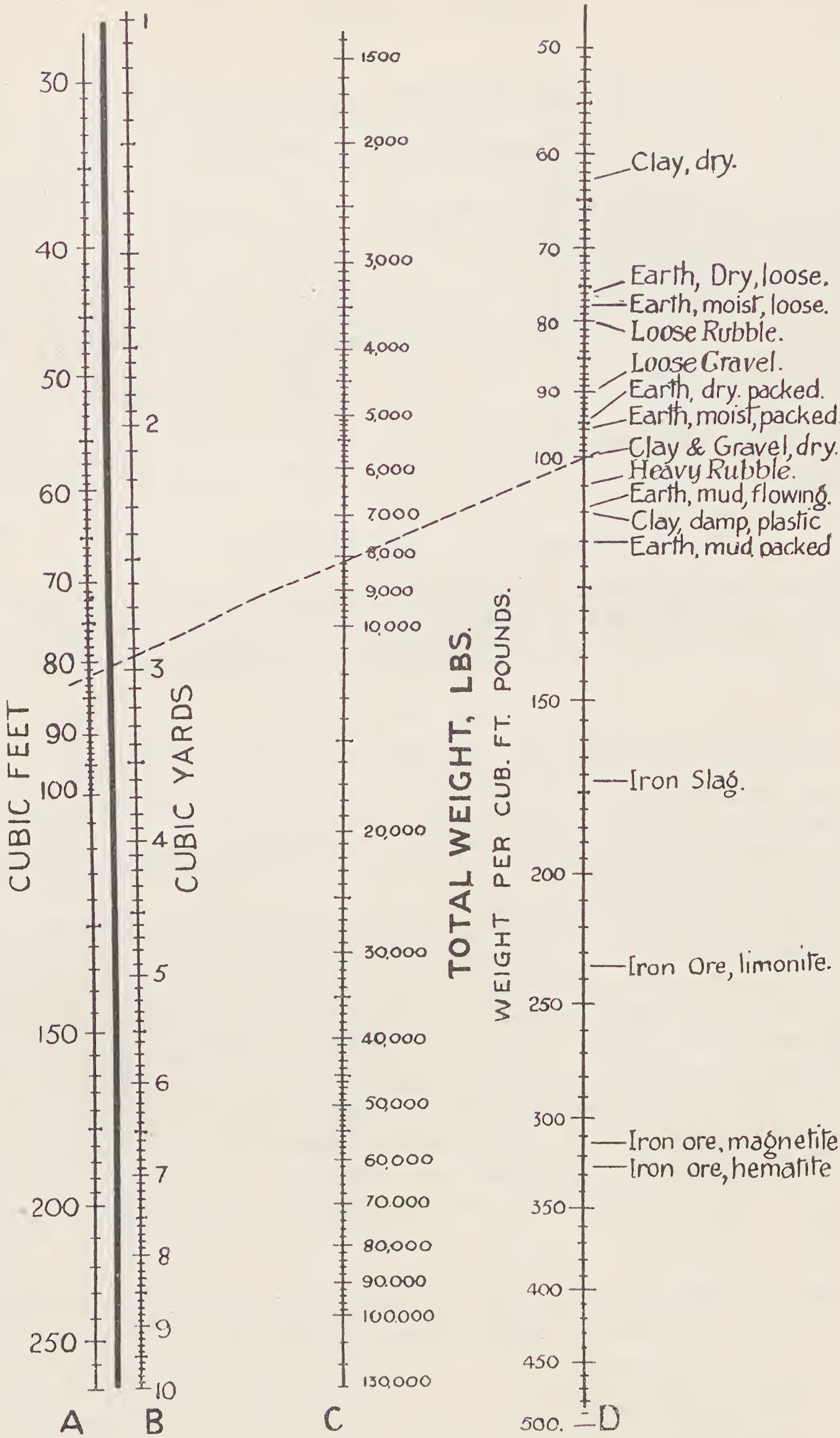

CUBIC FEET
CUBIC YARDS
TOTAL WEIGHT, LBS.
WEIGHT PER CUB. FT. POUNDS.
30
40
50
60
70
80
90
100
150
200
250
1
2
3
4
5
6
7
8
9
10
1500
2000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
20,000
30,000
40,000
50,000
60,000
70.000
80,000
90.000
100.000
130,000
50
60
70
80
90
100
150
200
250
300
350
400
450
500.
Clay, dry.
Earth, Dry, loose.
Earth, moist, loose.
Loose Rubble.
Loose Gravel.
Earth, dry. packed.
Earth, moist, packed
Clay & Gravel, dry.
Heavy Rubble.
Earth, mud, flowing.
Clay, damp, plastic
Earth, mud, packed
Iron Slag.
Iron Ore, limonite.
Iron ore, magnetite
Iron ore, hematite
A
B
C
D

Fig. 145.

EMBANKMENTS AND CUTTINGS

To increase stability of permanent embankments and cuttings, vary the inclination of slope, say from 3 to 1 at bottom to $1\frac{1}{2}$ to 1 at top. The rule for clay may be taken as $1\frac{1}{2}$ to 1 for a bank or cutting 5 feet high; 2 to 1 for 10 feet; 3 to 1 for 20 feet. Where possible the bank should be turfed.

In engineering work the safe slope, or angle of repose, for most soils is taken as $1\frac{1}{2}$ feet horizontal to 1 foot vertical, or in other words, to an angle of $33° 42'$.

RETAINING WALLS

$ah = 1$; $gj = \cdot 4$; $ab = \frac{1}{6}$; $gh = \frac{1}{12}$; cd, etc. = from 9 inches to 12 inches each, the distance ij to be divided up into steps of these widths (see Fig. 127).

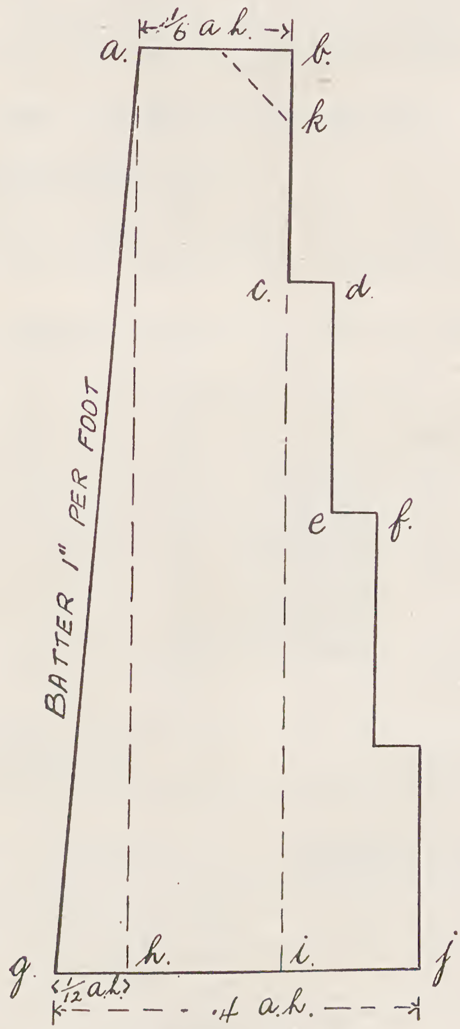


Fig. 146.—Retaining walls.

FOOTINGS

Thickness of wall in bricks.	Width of lowest course in bricks.	Height of footings in courses of 3 inches.
$\frac{1}{2}$	1	1
1	2	2
$1\frac{1}{2}$	3	3
2	4	4
$2\frac{1}{2}$	5	5
3	6	6
$3\frac{1}{2}$	7	7
4	8	8
$4\frac{1}{2}$	9	9
5	10	10
6	12	12

GRILLAGE FOUNDATIONS

(Steel joists embedded in concrete)

Formula:

$$M = \frac{w}{s}(l - x)$$

where w = total load on one joist; l = total length of joist; x = width of column base or next tier of joists above; s = tons per square foot on soil; M = bending moment.

SAFE LOADS FOR FOUNDATION SOILS

Material.	Ton per sq foot.
Granite formation	30
Limestone, compact beds	25
Sandstone, compact beds	20
Shale formation and soft friable rock	8–10
Chalk	4
Gravel and sand, compact	6–10
Gravel, dried and coarse, packed and confined	6
Gravel and sand, mixed with dry clay	4–6
Clay, dry sand in thick beds	4
Clay, moderately dry in thick beds	3
Clay, soft	1–1½
Sand, compact, well cemented and confined	4
Sand, clean and dry, in natural beds and confined	2
Earth, solid, dry, in natural beds	4

Formula for safe loads on piles:

$$\text{Safe load in cwts.} = \frac{wh}{8d}$$

where w = weight of ram in cwts.; h = height fallen through by ram in inches; d = distance driven by last blow in inches; 8 = a constant.

SOIL DRAINAGE

Type of soil.	Depth of pipes.		Distance of pipes apart.
	Feet.	Inches	Feet.
Loose or stony clay	2	0	18
Stiff clay	2	6	15
Soft clay	2	9	21
Clayey loam	3	2	21
Gravelly loam	3	3	27
Light loam	3	6	33
Sandy loam	3	9	40
Light gravelly sand	4	0	50
Coarse gravelly sand	4	6	60

TILES (PIPES) PER ACRE

Number of tiles required to drain one acre of land at different widths.

Distance square. Yards.	12-inch tiles.	15-inch tiles.	12-inch tiles.	To cuttings and embankments laid to angle of 45°. 15-inch tiles.
4	3,630	2,904	5,704	4,356
8	1,815	1,452	2,732	2,178
12	1,250	966	1,815	1,452

GRADIENT OF DRAINS

Maguire's rule: Fall equals one in (dia. in inc. × 10). This gives fall for 4-inch drain of 1 in 40, for 6-inch 1 in 60, and 9-inch 1 in 90. These are ideal gradients, but in practice may have to be greater or lesser.

III. TIMBER

TIMBER MEASURES

Laths are narrow strips 1 inch wide, between 2 feet and 5 feet long, singles $\frac{1}{2}$–$\frac{3}{16}$ inch thick, lath and a half $\frac{1}{4}$ inch thick, and doubles $\frac{3}{4}$–$\frac{1}{2}$ inch thick. They are made up in bundles of 200–300 feet run.

Scantlings are miscellaneous cut stuff, and the term is applied to the dimensions of such stuff.

A square equals 100 superficial, or square, feet.

A hundred of deals equals 120.

A load of timber equals 50 cu. feet of hewn timber, or 40 cu. feet of unhewn timber.

A float equals 18 loads.

Ends are short lengths of deals.

Slab stuff are the outer boards of logs or rough balks.

A load of 1-inch flooring boards equals 600 sq. feet.

A fathom equals 216 cu. feet ($6 \times 6 \times 6$ feet).

A cord equals 128 cu. feet.

A stack equals 108 cu. feet.

Petrograd Standard.—In Britain timber is measured in bulk by the Petrograd Standard of 165 cu. feet.

Board Standards.—12 12-foot boards, 9 inches wide, laid rough; or $12\frac{1}{2}$ 12-foot boards, 9 inches wide, edges shot; or 13 12-foot boards, 9 inches wide, wrought and laid folding; or 14 12-foot boards, 9 inches wide, wrought and laid straight joint, all equal 1 square.

Deal Standards: Baltic—120 pieces 12 feet $\times$ 11 inches $\times$ $1\frac{1}{2}$ inches equal 1,320 sq. feet, or 270 cu. feet; London and Dublin—120 pieces 12 feet $\times$ 9 inches $\times$ 3 inches equal 1,080 sq. feet, or 270 cu. feet; Quebec (long)—120 pieces 10 feet $\times$ 11 inches $\times$ 3 inches equal 1,100 sq. feet; Quebec (short)—100 pieces 12 feet $\times$ 11 inches $\times$ $2\frac{1}{2}$ inches equal 1,100 sq. feet, or $229\frac{1}{2}$ cu. feet.

Batten Standards.—16 12-foot battens, 7 inches wide, laid rough; or $16\frac{1}{2}$ 12-foot battens, 7 inches wide, edges shot; or 17 12-foot battens, 7 inches wide, laid folding; or 18 12-foot battens, 7 inches wide, straight jointed, all equal 1 square.

400 feet super of $1\frac{1}{2}$-inch deal equal 1 load; 600 feet super of 1-inch deal equal 1 load. 100 12-foot 3-inch deals, 9 inches wide, equal $5\frac{2}{3}$ loads; 100 12-foot $2\frac{1}{2}$-inch deals, 9 inches wide, equal $4\frac{1}{2}$ loads.

Timber is usually cut to exact thickness, and there is a loss of about $\frac{1}{8}$ inch in planing.

Four score of 6-foot, 5 score of 5-foot, and 6 score of 4-foot cleft oak pales go to the hundred.

Superficial Measure.—To find the superficial area (or sq. feet) of planks, boards, deals, etc., multiply length by width (reducing to inches), and divide by 12, which will give the result in feet and (the number left over) inches, if any.

To Cube Squared Timber.—If of equal dimensions throughout length, multiply width by thickness and the result by length. If tapering, square both extremities, add together, divide by 2, and multiply result by length.

To Cube Logs.—(1) Take the diameter of the log at the middle, ascertain the area of such diameter by referring to the tables of Areas of Circles, and multiply this by length. Or (2) ascertain area, or square measurement, of the two extremities (as above), add together, divide by 2, and multiply result by length. Or (3) multiply length of log in feet by $\frac{1}{4}$ average girth of log in inches and divide by 144.

To Ascertain Square Cubic Content of Rough Log.—Ascertain diameter of middle of log (or average diameters of the two extremities, as explained above), reduce by $\frac{1}{3}$ to allow wastage in slabbing, square the width, and multiply by length.

Weight of Woods.—66 cu. feet of deals, or 64 cu. feet of fir, or 60 cu. feet of elm, or 51 cu. feet of beech, or 45 cu. feet of ash, or 39 cu. feet of oak, or 35 cu. feet of mahogany will weigh approximately 1 ton. 40 cu. feet of rough or 50 cu. feet of hewn timber equal 1 ton or load; 108 cu. feet equal 1 stack of wood; 128 cu. feet equal 1 cord of wood.

TO ASCERTAIN PRICE OF DEALS

When the price per hundred (120) is known, to ascertain price of each deal multiply the number of pounds sterling by 2, the product being the price in pence per deal.

If the price per deal be known, to ascertain the price per hundred (120) reduce the value into pence, divide by 2, and the product will be pounds sterling per hundred.

NOMINAL AND EFFECTIVE BOARD MEASURES

Width of boards.	Per cent. increase for	
Inches.	Rebated joint.	Tongue and grooved.
3	4½	9
3½	3¾	8½
4	3¼	6½
4½	2¾	5½
5	2½	5
5½	2¼	4½
6	2	4

Plus 5 per cent. for general cutting and waste.

TO ASCERTAIN BREAKING WEIGHT AND SAFE LOAD OF WOODEN BEAMS

For breaking weight in cwts., multiply the width squared by the depth, and the product by a constant (which for fir and red pine is 4 for a load in centre and 8 for distributed load), and divide the result by the length of the beam.

For safe load divide the constants by 4.

In rectangular timbers breadth should be $\frac{2}{3}$ of depths.

PHYSICAL PROPERTIES OF TIMBERS

(Compiled from data recorded by T. Laslett)

Timber.	Deflection under 300-lb. load. Inches.	Deflection after removal of load. Inches.	Deflection at breaking. Inches.	Breaking load in lb.	Crushing load, tons per 2 cu. inches.
Ash : Canadian	2·75	0·125	7·375	638	9·812
Ash : English	1·625	0·95	8·625	862	12·437
Cedar : Cuban	2·266	0·258	4·316	560	8
Elm : English	4·90	1·30	5·291	460	10·333
Greenheart	2·15	0·066	4·625	1332·5	27·278
Blue gum	1·26	0·10	4·21	712	12·312
Jarrah	3·21	0·133	4·71	685·66	12·792
Karri	1·01	0·04	6·06	862·5	185 *
Larch : Russian	1·566	0·175	4·33	626	10·687
Mahogany : Cuban	1·208	0·025	5·45	856·16	13
Mahogany : Honduras	1·916	0·083	4·058	802	11
Mahogany : Mexican	1·125	0·058	3·925	782·5	10·531
Oak : American	1·475	0·191	8·833	722·66	10·521
Oak : Danzig	5·00	0·24	6·453	473·5	13·969 †
Oak : English	3·375	0·189	7·354	776	13·646
Pine : Kauri	1·225	0·083	3·916	815·5	10·50
Pine : American pitch	1·125	0·075	3·953	1049·5	11·542
Pine : Baltic red	1·625	0·066	5·142	876·66	12·687
Pine : Canadian red	1·665	0·133	4·625	653·33	8·46
Pine : Canadian yellow	2·125	0·833	4·66	626·6	7·454
Pine : Riga	1·292	0·92	3·625	600	8·437
Spruce : Canadian	1·225	0·058	5·187	670	8·666
Teak : Burma	1·65	0·083	5·375	912·66	11·354

* 6 cu. inches. † 2 × 2 × 1 inch.

IV. BRICKWORK, MASONRY, CONCRETE, AND PAVING

BRICKWORK

Standard sizes of brick :

Size I . . . $8\frac{3}{4} \times 4\frac{3}{16} \times 2$ inches.
,, II . . . $8\frac{3}{4} \times 4\frac{3}{16} \times 2\frac{5}{8}$,,
,, III . . . $8\frac{3}{4} \times 4\frac{3}{16} \times 2\frac{7}{8}$,,

A rod of brickwork equals 306 cu. feet (actually 306·28 cu. feet), and will contain from 4,200 to 4,500 bricks, according to dimensions and character of jointing. A rod of brickwork requires 2 cu. yards of mortar with Size III bricks and $\frac{1}{4}$-inch joints, or nearly 3 cu. yards with $\frac{3}{8}$-inch joints. On an average 1 rod of brickwork will equal 272 sq. feet of $1\frac{1}{2}$-brick walling, or 408 sq. feet of 1-brick walling.

To ascertain the number of bricks in brickwork, multiply the height by the length and the result by the thickness. An allowance can be made for jointing. This cubing, reduced to the cube yard, is generally adopted for estimating and pricing engineering and other heavy work.

Given the thickness of the walling, stated in inches or in units of brick thickness, the superficial area is ascertained by multiplying height by length.

In most cases, however, measuring is stated in terms of "reduced brickwork," that is to say, reduced to the accepted standard of a rod of brickwork 272 sq. feet $1\frac{1}{2}$ bricks thick. This is done by multiplying the

superficial area of the wall by the number of half bricks in the thickness, dividing by 3 to ascertain the number of sq. feet at standard thickness, and divide by 272 to reduce to rods. Of course, if the walling is of standard thickness, it is only necessary to divide the superficial area by 272.

To reduce cu. feet of brickwork to standard thickness, multiply the number of cu. feet by 8 and divide by 9. The result can be divided by 272 to obtain statement in rods of standard thickness.

WEIGHT OF BRICKWORK

(Building Research Station)

Type of brickwork.	Average weight of bricks. Dry. Lb.	Dry. Oz.	Wet. Lb.	Wet. Oz.	Actual weight of brickwork in lime mortar per cu. foot. Lb.
Stafford blue	9	3	9	10	150
Accrington engineering	8	12	8	12½	133
Flettons	5	6	6	5	113
Cavity flettons	4	4	4	15	89
Iver stocks	5	3	5	12	104
Leicester red, wire cut	4	8	5	11	91
Sand lime	6	8	7		115

STRENGTH OF BRICK WALLING

(Building Research Station)

Description.	Crushing strength of cubes. Lb. per sq. in. 9 × 9 × 9 inches.	Age of cube. Days.	Crushing strength of wall 12 feet wide by 8 feet 6 inches high. Lb. per sq. inch.	Age of wall.	Horizontal rule to break wall 3 feet 6 inches × 5 feet 6 inches high, under vertical load of 1 ton.	Age when wall was tested under horizontal pull.
Stock, bricks, 3 to 1 cement mortar, 4½ inches thick	—	26	638	24	895 *	34
Stock bricks, 6 to 1 cement mortar	720	26	562	23	791	41
Flettons, 3 to 1 cement mortar, wall 4½ inches thick	1,530	26	1,040	24	781	39
Flettons, 6 to 1 cement mortar, wall 4½ inches thick	1,250	26	930	23	705	36
Flettons, 3 to 1 lime mortar, wall 4½ inches thick	1,050	22	330	24	375	27
Flettons on edge, 3 to 1 cement mortar, wall 2⅝ inches thick, cast in one piece	1,470	29	1,040	23	553	44

* In this specimen a vertical load of 2 tons per foot run was applied in connection with horizontal pull test.

CAVITY BRICKS: STRENGTH

(Building Research Station)

Cavity bricks as individual units had only 35 per cent. of the crushing strength of selected flettons, with frog filled, but when built in wall with mortar of rapid-hardening Portland cement and Leighton Buzzard sand, 1 : 3, at 7 days, the first signs of cracking of cavity bricks appeared under a load of 75 tons per sq. foot, flettons 62·5 tons. Final crushing the cavity-brick wall showed 77 per cent. of the fletton-brick value.

REINFORCED BRICKWORK

Strips of expanded metal and of wire mesh, also steel rods, are used in reinforced brickwork.

Brick walling of common stocks, having an ultimate crushing strength of 4,080 pounds per sq. inch, with an absorption point of 10 per cent., set in mortar composed of 1 part cement to 2 parts sand, reinforced with strips of wire mesh, were found to have an ultimate shear strength of 168 pounds per sq. inch, with a working strength of 42 pounds and a safety factor of 4. Beams of brickwork reinforced with $\frac{3}{4}$-inch rods, $3\frac{3}{4}$ inches deep by $4\frac{5}{8}$ inches wide, the rods placed in two rows towards the base, tested on a free span of 32 inches, supported at both ends on 2-inch bearings, had an ultimate breaking strain of 2,590 pounds per sq. inch ; shearing strength (to breaking) 185 pounds per sq. inch ; working strength 46 pounds with factor of safety of 4.

Strips between horizontal courses must be completely covered by both bricks and mortar ; 2–4-inch laps, laced with galvanised wire, ends bent upwards or downwards, or split to bend upwards and downwards for 2 to 3 courses. Over openings, square or arched, over windows, doorways, passages, etc., first, second, and third courses should be reinforced (over small squares with light super loads, two courses sufficient), the reinforcement to be carried not less than $\frac{1}{4}$ square on each side, the ends turned up or down and tailed into brickwork. In arches, reinforcement is placed between the rings, carried well down below skewbacks, for not less than 6 inches in horizontal course, and ends, not less than 2 inches, bent up and down, tailed into brickwork.

Steel rods, $\frac{1}{4}$–$\frac{3}{4}$ inch in diameter, can be placed vertically and horizontally. Vertically tied by galvanised wire to horizontal strip reinforcement. Also for angle reinforcement in walls, reservoirs, etc. Horizontal rods chiefly useful in beams and lintels. Lintels, 8–12 inches wide and $17\frac{1}{2}$ inches deep, should be reinforced with $\frac{1}{4}$-inch round rods, placed towards the base, tied by steel hooks and wire buoys, brickwork bedded in lime or cement mortar, the latter with from 10 to 15 per cent. (dry) of hydrated lime. Beams up to 20-foot span, about 9 inches wide and 25 inches deep, to be reinforced with five $\frac{3}{4}$-inch rods, well secured by means of loops uniting the hooked ends.

ESTIMATING CONTENTS OF A STACK OF BRICKS OR CONCRETE BLOCKS

The chart on Fig. 147 permits of a rapid estimate of the number of bricks or concrete blocks in a stack or dump. The middle column is adjusted to standard brick sizes. To use the chart, cube the mass, and place a ruler or straightedge across the three columns, adjusting it on the right-hand column to the cubic measurement of the stack and on the left column to the number of bricks or blocks in a cu. foot. The point of

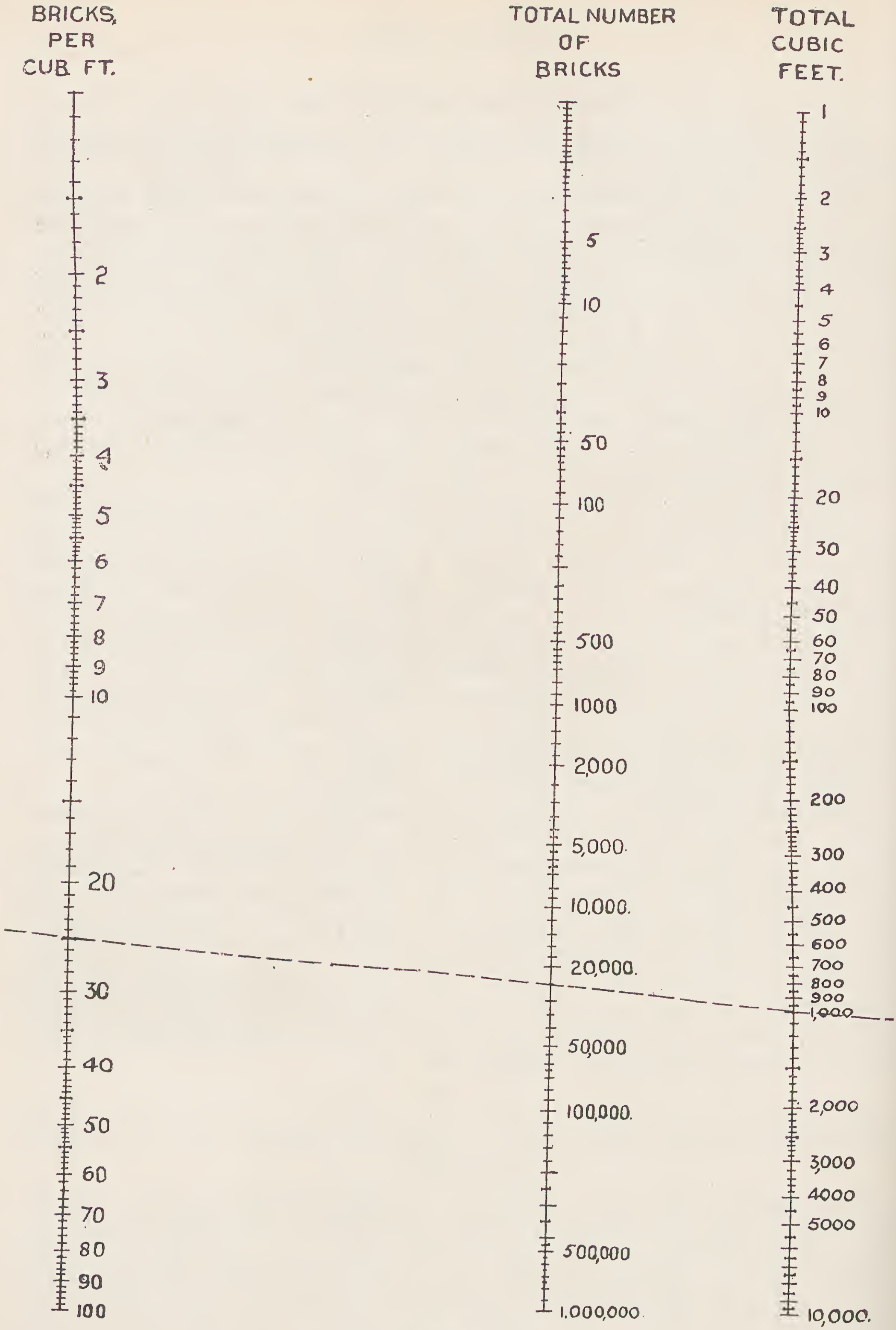

BRICKS PER CUB. FT.
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
TOTAL NUMBER OF BRICKS
5
10
50
100
500
1000
2,000
5,000.
10,000.
20,000.
50,000
100,000.
500,000
1,000,000.
TOTAL CUBIC FEET.
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1,000
2,000
3,000
4000
5000
10,000.

Fig. 147

intersection in the middle column will give a fairly close estimate of the number in the stack, errors due to tight or loose packing excepted.

FACE OF ARCHES

Span in feet	Ordinary Vaults, Bridges. etc.									
	Semicircular.					Arches of 120°.				
	Block stone.		Brick.	Rubble.		Block stone.		Brick.	Rubble.	
	Feet.	Inches.	Feet.	Feet.	Inches.	Feet.	Inches.	Feet.	Feet.	Inches.
5 or under .	0	8	1	0	10	0	9	1	0	10½
6 or under .	0	9	1	0	11	0	10	1	1	0
8 or under .	0	10	1	1	0	0	11	1½	1	1½
10 or under .	0	11	1½	1	1½	1	0	1½	1	3
12 or under .	1	0	1½	1	3	1	1	1½	1	4½
14 or under .	1	1	1½	1	4	1	2	1½	1	6
16 or under .	1	2	1½	1	5	1	3	2	1	7
18 or under .	1	3	2	1	6	1	4	2	1	8
20 or under .	1	4	2	1	7	1	5	2	1	9
22 or under .	1	5	2	1	8	1	6	2	1	10½
24 or under .	1	6	2	1	9	1	7	2½	2	6

The formula for finding the thickness of arch or depth of keystone is as follows :

Depth of keystone $= n\sqrt{\text{radius of crown}}$ where $n = 0{\cdot}3$ for block stone ; $0{\cdot}4$ for brickwork ; $0{\cdot}45$ for rubble stonework, dimensions in feet.

For straight arches :

$$\text{Depth of keystone} = n\sqrt{\text{span}} + \frac{\text{span}}{12}.$$

WEIGHT OF GRANITES

Description.	Place of origin.	Weight per cu. foot in lb.
Dalkey	Dublin	169
Hay Tor	Devonshire	165
Blue Penmaenmawr . . .	Carnarvonshire	160
Aberdeen grey	Aberdeenshire	166
Aberdeen red	Aberdeenshire	165
Cornish grey.	Cornwall	167
Cornish red	Cornwall	164
Bon Accord red	Sweden	168
Labradorite : Emerald pearl . .	Norway	168
Labradorite : Royal blue . .	Norway	168
Carnation	Sweden	168
Ruby red	Sweden	168

MEASURING STONEWORK

Stonework is generally cubed (= length × width × height) and finished labour charged extra. But stone 3 inches thick and under and plain ashlar per foot super. Circular, sunk, and all finished work per foot super.

STRENGTH OF STONES

(From Prof T. Hudson Beare)

Description.	Co-efficient of elasticity. On re-application of load. Tons per sq. foot.	Range of stress. Tons per sq. foot.	Crushing load (mean). Tons per sq. foot.
Limestones :			
Ancaster brown, weatherbed.	499,800	32·1–172·8	552·6
Portland Whitbed *	236,900	16·07–64·28	204·7
Portland basebed	—	—	287·0
Ketton	156,900	16·07–64·28	101·7
Corsham Down	116,000	16·07–64·28	109·5
Farleigh Down *	72,460	16·07–64·28	64·8
Box ground	129,200	16·07–64·28	97·5
Stoke ground *	109,300	32·14–80·35	98·0
Westwood ground	128,900	16·07–64·28	122·8
Doulting fine beds	121,000	31·14–80·35	111·6
Doulting Chelynch bed	379,000	32·14–112·49	180·8
Ham Hill	164,500	32·14–112·49	166·3
Ancaster freestone	130,500	16·07–96·42	184·0
Yellow Mansfield *	406,100	32·1–192·8	577·4
Hopton wood	—	—	811·4
Sandstones :			
Prudham	125,300	32·1–128·6	455·3
Craigleigh	—	—	861·9
Corsehill	121,000	32·1–192·8	444·9
Forest of Dean (grey)	172,000	32·1–192·8	530·0
Forest of Dean (blue)	—	—	631·7
Howley Park	116,500	32·1–192·8	466·7
White Grinshill	115,500	32·1–128·4	209·3
Bramley Fall	114,900	32·1–128·4	238·4
Ackworth	90,960	32·1–128·4	389·1

* Coefficient of elasticity when stone having undergone compression is at ease.

CRUSHING STRENGTH OF MARBLES

	Tons per sq. foot
White Italian	1,400
White Statuary	206–389
Purbeck	587

THICKNESS FOR MARBLE TILES

	¾ inch thick. Inches.	1 inch thick. Inches.	1½ inches thick. Inches.
Tiles not exceeding	18 × 18	27 × 27	36 × 36
Borders and strips not exceeding	30 × 12	40 × 18	50 × 24

FORMULA FOR AMOUNT OF WATER IN MORTARS

$$w = \frac{2}{3}\left(\frac{P}{S + 1}\right) + 6\cdot5,$$

where w = percentage of water for water in terms of weight of the mixture of materials ; P = percentage of water required for neat cement,

as determined by the Vicat-plunger method ; S = parts of sand by weight to 1 part of cement. For dry mortars use 4·5 instead of 6·5.

Alternatively :

$$w = \frac{P}{6} + 6{\cdot}5.$$

Or :

$$w = \frac{3P + Sn + 1}{4(n + 1)},$$

where w = percentage of water for sand mortar ; P = predetermined percentage of water required to bring neat cement to required consistence ; n = parts of sand to 1 of cement by weight ; S = constant depending on the character of sand and consistence required, varying between 25 and 33.

British Standard Specification :

$$w = \tfrac{1}{4}P + 2{\cdot}5,$$

where w = percentage of water for 1 : 3 mortar in terms of weight of the dry materials ; P = percentage of water required for the preparation of neat cement paste that is plastic when filled into a mould for forming test briquettes.

STRENGTH OF 1 : 3 SAND MORTAR

(Building Research Station)

Cement.	Percentage mixing water.	Percentage mortar voids.	Breaking strength in lb. per sq. inch.						
			1 day.	2 days.	3 days.	7 days.	28 days.	3 months.	12 months.
British Portland (briquettes stored in water after 1 day in air)	8	32·0	91	—	282	398	472	510	—
	9	30·3	60	—	247	362	502	575	—
	10	32·2	40	—	210	366	460	500	—
	11	33·7	53	—	196	397	430	440	—
	12	34·5	37	—	218	278	435	500	—
British High Alumina Cement (stored as above)	8	31·2	485	587	574	633	591	625	655
	9	30·8	475	480	537	562	578	592	692
	10	31·8	398	437	457	530	552	525	630
	11	32·8	412	434	442	462	496	511	594
	12	34·5	356	448	451	377	443	459	549
" Ciment Fondu " (stored as above)	8	32·1	330	352	—	371	414	390	376
	9	31·2	290	331	—	385	362	368	369
	10	32·0	310	338	—	344	337	317	425
	11	32·6	230	295	—	355	329	286	351
	12	33·0	250	297	—	343	302	311	316
" Rapid-hardening Cement " (stored as above)	8	31·7	104	—	432	540	572	519	536
	9	31·0	121	—	432	507	544	557	516
	10	31·6	118	—	345	471	513	527	513
	11	33·4	100	—	337	413	507	478	503
	12	35·4	73	—	301	374	492	481	427

RELATIVE WEIGHTS OF CEMENT AND LIME MORTARS

(Building Research Station)

Average weight of 1 : 3 cement mortar, 8·7 lb. per 100 cu. inch ; 1 : 3 lime mortar, 5·9 lb. per 100 cu. inch. 9-inch brick walls with $\frac{3}{8}$-inch wide

joints in 1 : 3 cement mortar and 1 : 3 lime mortar, difference of 9·3 lb. per cu. foot in favour of lime mortar.

TENSILE STRENGTH OF MORTARS

Lb. per sq. inch.

Age of samples.	1 lime, 3 sand.	1 lime, 6 sand.
2 weeks	103	45
4 weeks	123	58
26 weeks	234	124
1 year	238	154
2 years	272	162
3 years	286	168

ADHESIVE STRENGTH OF MORTARS

Fat lime 1 part, sand 2 parts	$4\frac{3}{4}$ lb. per sq. inch.
Lias lime 1 part, sand 2 parts	9 lb. per sq. inch.
Lias lime 1 part, sand 4 parts	$6\frac{3}{4}$ lb. per sq. inch.
Portland cement 1 part, sand 4 parts	23 lb. per sq. inch.
Portland cement 1 part, sand 6 parts	$15\frac{1}{2}$ lb. per sq. inch.

CEMENT RENDERING : QUANTITIES

Mixture	Thickness.				
	1 inch.	$\frac{7}{8}$ inch.	$\frac{3}{4}$ inch.	$\frac{5}{8}$ inch.	$\frac{1}{2}$ inch.
1 bushel cement, neat	$1\frac{1}{7}$	$1\frac{3}{4}$	$1\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{1}{2}$
1 bushel cement, 1 bushel sand	$2\frac{1}{4}$	$2\frac{3}{4}$	3	4	$4\frac{1}{2}$
1 bushel cement, 2 bushels sand	$3\frac{1}{3}$	$4\frac{1}{4}$	$4\frac{1}{2}$	6	$6\frac{3}{4}$
1 bushel cement, 3 bushels sand	$4\frac{1}{2}$	$5\frac{1}{2}$	6	8	9

LIME PLASTERS : QUANTITIES

100 yards of rendering requires 1 cu. yard of lime, 1 cu. yard of sand, 16 lb. of hair ; of rendering and setting, 2 cu. yards of lime, 2 cu. yards of sand, 19 lb. of hair ; of 2-coat work and set, 3 cu. yards of lime, $2\frac{1}{2}$ cu. yards of sand, 19 lb. of hair ; of rendering and floating, 2 cu. yards of lime, 3 cu. yards of sand, 15 lb. of hair ; of rendering, floating, and setting, 3 cu. yards of lime, 3 cu. yards of sand, 21 lb. of hair. Three-coat work on brick requires $2\frac{1}{3}$ cu. yards of lime, $2\frac{1}{3}$ cu. yards of sand, 30 lb. of hair ; on laths, 22 bundles of laths, 14 lb. of nails, $2\frac{1}{2}$ cu. yards of lime, $2\frac{1}{2}$ cu. yards of sand, 32 lb. of hair per 100 yards super.

STRENGTH OF PIERS

(Hurst)

Composition of pier : height under 12 times least thickness:	Weight on which fracture begins. Tons per sq. foot.
Bricks, best hard stocks, set in Portland cement and sand, 1–3 months old	40
Bricks, well-burnt London stocks in cement and sand	30
Bricks, hard stocks in Roman cement and sand	28
Bricks, hard stocks in lias lime and sand, 1 : 2, 6 months old	24
Bricks, hard stocks in grey lime and sand, 1 : 2, 6 months old	12

Strength of Piers (Hurst)—*cont.*

	Weight on which fracture begins. Tons per sq. foot
Rubble masonry, flat-bedded stones, lias lime and sand, 1 : 2, 6 months old	40
Rubble masonry, irregularly shaped stones, lias lime and sand, 1 : 2, 6 months old	15
Concrete in foundations, Portland 1, gravel 5, sand 1, 3 months old	40
Concrete in foundations, Portland, blue lias lime 1, gravel 5, sand 1, in moist ground	20
Portland cement neat, 3 months old	152
Portland cement and sand, equal parts	100
Portland cement, 1 : 4	72
Portland cement neat, 9 months old	240
Portland cement and sand, equal parts, 9 months	181

Safe load, one-fifth of above ; live loads unequally distributed, one-eighth.

WEIGHT OF MASONRY, BRICKWORK, AND CONCRETE

(Averages)

Material.	Weight per cu. foot in pounds.
Bath stone	123
Limestone	195
Sandstone	152
Granite	166
Marble	170
Portland stone	135–145
Slate	160–180
York stone	130–150
Rubble masonry	140
Terra-cotta, hollow	60–70
Terra-cotta, solid	120
Ordinary brickwork in lime mortar	112
Ordinary brickwork in cement mortar	115
Staffordshire bricks in cement mortar	135
Coke breeze, concrete	90–100
Concrete, clinker	100
Concrete, ballast	145
Concrete, limestone	135
Concrete, reinforced	150

$13\frac{1}{2}$ cu. feet of granite, $13\frac{3}{4}$ cu. feet of Purbeck stone, $14\frac{1}{2}$ cu. feet of Yorkshire, $14\frac{3}{4}$ feet of Portland or Craigeigh, 15 cu. feet of Derby, 16 cu. feet of Bath weigh approximately 1 ton.

STRENGTH OF THIN CONCRETE WALLS

(Building Research Station)

Description.	Crushing strength. Cubes. Lb. per sq. inch.	Age at test.	Crushing strength of wall 14 inches wide by 8 feet 6 inches high. Lb. per sq. inch.	Age of wall at test.	Horizontal pull to break down wall 3 feet 6 inches wide by 8 feet 6 inches high under vertical load of 1 ton per foot run.	Age of wall at horizontal pull test.
Concrete, 1 : 2 : 4 wall, $4\frac{1}{2}$ inches thick	1,480 2,250	22 42	1,230	26	1,262	27
Concrete blocks, 1 : 2 : 4, set in 3 to 1 cement mortar wall, $4\frac{1}{2}$ inches thick, $14 \times 9 \times 4\frac{1}{2}$ inches	1,480 2,250	22 42	1,510	22	1,253	25
Concrete blocks (weight 4 : 2 : 1) wall, $4\frac{1}{2}$ inches thick	Block. $6 \times 6 \times 4\frac{1}{2}$ inches, 743 *	120	580	24	962	44
Concrete blocks, 4 : 2 : 1 (wet process), wall 3 inches thick	$6 \times 6 \times 6$ inches, $6 \times 6 \times 3$ inches, 1,240 *	29 29	1,130	24	700	32
Coke breeze blocks wall, 3 inches thick	$6 \times 6 \times 3$ inches, 236 *	—	170	22	467 (slab)	41
Coke breeze blocks wall, 4 inches thick	$6 \times 6 \times 4$ inches, 243 *	—	173	22	658 (slab)	41

* These specimens were cut from larger blocks as true as possible, but not faced, and no doubt were really stronger than the tests indicate.

MATERIALS REQUIRED FOR CONCRETE FLOORS OR ROADS, PER SQUARE YARD

Proportions.	Materials.	4 in. thick.	4½ in. thick.	5 in. thick.	5½ in. thick.	6 in. thick.	6½ in. thick.	7 in. thick.	7½ in. thick.	8 in. thick.	8½ in. thick.	9 in. thick.	9½ in. thick.	10 in. thick.	11 in. thick.	12 in. thick.
1 : 1½ : 3	*Cement . lb.	75·7	85·1	94·6	104	113·5	123	132·4	141·9	151·4	160·8	170	179·7	189·2	208·1	227
	Sand . . cu. ft.	1·31	1·47	1·63	1·80	1·97	2·13	2·30	2·46	2·62	2·78	2·95	3·11	3·27	4·61	3·93
	Coarse matl. cu. ft.	2·62	2·95	3·27	3·60	3·93	4·26	4·59	4·91	5·24	5·57	5·9	6·22	6·54	7·21	7·87
1 : 2 : 4	*Cement . lb.	59·3	66·75	74·16	81·58	89	96·42	103·83	111·25	118·66	126·08	133·5	140·92	148·33	163·16	178
	Sand . . cu. ft.	1·32	1·485	1·65	1·82	1·98	2·15	2·31	2·48	2·64	2·81	2·97	3·14	3·3	3·63	3·96
	Coarse matl. cu. ft.	2·64	2·97	3·3	3·63	3·96	4·29	4·62	4·95	5·28	5·61	5·94	6·27	6·6	7·26	7·92
1 : 2½ : 5	*Cement . lb.	48·9	55	61·1	67·2	73·3	79·4	85·5	91·6	97·7	103·8	110	116·1	122·2	134·4	146·6
	Sand . . cu. ft.	1·35	1·52	1·69	1·86	2·03	2·19	2·36	2·53	2·7	2·87	3·04	3·21	3·38	3·71	4·05
	Coarse matl. cu. ft.	2·7	3·04	3·38	3·72	4·05	4·39	4·73	5·06	5·4	5·74	6·08	6·41	6·75	7·43	8·1
1 : 3 : 6	*Cement . lb.	41·5	46·69	51·88	57·07	62·25	67·44	72·63	77·82	83	88·19	93·38	98·57	103·76	144·14	124·5
	Sand . . cu. ft.	1·43	1·62	1·79	1·97	2·15	2·33	2·51	2·69	2·87	3·05	3·23	3·41	3·58	3·95	4·3
	Coarse matl. cu. ft.	2·86	3·23	3·58	3·94	4·3	4·66	5·02	5·38	5·74	6·1	6·46	6·82	7·16	7·9	8·6

* Based on loose cement weighing 90 lb. per cu. foot.

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"WORKABILITY" OF CONCRETE

The following are results of experiments carried out at the Building Research Station to determine the influence of consistence on the time of placing concrete in reinforced work.

Water Cement Ratio (by weight).	Time in filling, minutes.	Remarks.
0·50	11·0	Needed much ramming, was difficult to finish off.
0·60	7·25	Needed ramming.*
0·70	4·25	Becoming "plastic," easier to place and finish off.*
0·80	3·5	* Very easy to fill into moulds.†
0·90	3·0	Becoming "sloppy" and poured into moulds ‡
1 0	2·75	Very wet and "sloppy"; water flowing out of the concrete carried away the necessary finer cement.

* Given by a "slump" of about 1 inch. Recommended where light tamping is practicable.
† Given by a "slump" of 4–6 inches. Suitable for reinforced floor construction.
‡ Given by a "slump" of about 7 inches. The wettest mix that should be used for reinforced concrete work.

ROUND AND SQUARE REINFORCEMENTS

1 cu. foot steel = 489 pounds

Diameter in inches.	Weight per foot run.		Area of ○ bar in square inches.	Area of □ bar in inches.	Circumference of ○ bar.
	of ○ bar.	of □ bar.			
$\frac{3}{16}$	·094	·119	·0276	·0352	·589
$\frac{1}{4}$	·167	·212	·0491	·0625	·7854
$\frac{5}{16}$	·261	·333	0767	·0977	·9817
$\frac{3}{8}$	·375	·478	·1104	·1406	1·1781
$\frac{7}{16}$	·511	·651	·1503	·1914	1·3744
$\frac{1}{2}$	·667	·850	·1963	·2500	1 5708
$\frac{9}{16}$	·845	1·076	·2485	3164	1·7671
$\frac{5}{8}$	1·043	1·328	·3068	·3966	1·9635
$\frac{11}{16}$	1·262	1·608	·3712	·4727	2 1598
$\frac{3}{4}$	1·502	1·913	·4418	·5625	2·3562
$\frac{13}{16}$	1·763	2·245	·5185	·6602	2·5525
$\frac{7}{8}$	2·044	2·603	·6013	·7656	2·7489
$\frac{15}{16}$	2·347	2·989	6903	·8789	2·9452
1	2·67	3·4	·7854	1·000	3 1416
$\frac{1}{16}$	3·014	3·838	·8866	1·289	3·5379
$\frac{1}{8}$	3·379	4·303	·9945	1·2656	3·5343
$\frac{3}{16}$	3·766	4·793	1·1075	1·4102	3·7306
$\frac{1}{4}$	4·172	5·312	1·2272	1·5625	3·927
$\frac{5}{16}$	4·6	5·857	1·353	1·7227	4·1233
$\frac{3}{8}$	5·049	6·428	1 4849	1·8906	4·3197
$\frac{7}{16}$	5 518	7·026	1·623	2·0664	4 5160
$\frac{1}{2}$	6·008	7·65	1·7671	2·25	4 7124
$\frac{9}{16}$	6·52	8·301	1·9175	2·4414	4·9084
$\frac{5}{8}$	7·051	8·978	2·0739	2·6404	5 1051
$\frac{11}{16}$	7·604	9·682	2·2365	2·8477	5·3014
$\frac{3}{4}$	8·178	10·41	2·4053	3·0625	5 4978
$\frac{13}{16}$	8·773	11·17	2·5802	3·2852	5·6941
$\frac{7}{8}$	9·380	11 95	2·7612	3 5156	5·8905
$\frac{15}{16}$	10·02	12·76	2·9483	3 7539	6·0868
2	10·68	13·6	3·1416	4·000	6 2832

Hoops and bands: $\frac{3}{8}$ inch wide, gauges 1 to 26, and $\frac{1}{32}$ inch, $\frac{3}{64}$ inch, $\frac{1}{16}$ inch, $\frac{5}{64}$ inch, $\frac{3}{32}$ inch, $\frac{7}{64}$ inch, $\frac{1}{8}$ inch, $\frac{9}{64}$ inch, $\frac{5}{32}$ inch, $\frac{11}{64}$ inch, $\frac{3}{16}$ inch. Flats: $\frac{5}{8}$ inch wide, $\frac{3}{16}$–$\frac{5}{8}$ inch thick; $\frac{3}{4}$ inch wide, $\frac{3}{16}$–$\frac{3}{4}$ inch thick;

$\frac{7}{8}$ inch, 1 inch, $1\frac{1}{8}$ inches, $1\frac{1}{4}$ inches, $1\frac{3}{8}$ inches, $\frac{3}{16}$–$\frac{7}{8}$ inch wide; $1\frac{1}{2}$ inches, $1\frac{5}{8}$ inches, $1\frac{3}{4}$ inches, $1\frac{7}{8}$ inches, 2 inches, $2\frac{1}{4}$ inches, $2\frac{3}{8}$ inches, $2\frac{1}{2}$ inches, $2\frac{5}{8}$ inches, $2\frac{3}{4}$ inches, 5 inches wide by from $\frac{3}{16}$ inch to 1 inch thick.

LOSS OF STRENGTH IN CONCRETE AFTER HEATING

(Building Research Station)

Details of concrete, parts by volume.	Normal strength in lb. per sq. inch.	Strength after heating (average of 3 tests) 1,312° F. On cooling. Lb. per sq. inch.	1,312° F. Per cent. loss.	1,832° F. On cooling. Lb. per sq. inch.	1,832° F. Per cent. loss
1 Portland blast-furnace cement $1\frac{1}{2}$ dolerite (Rowley Regis) sand, $\frac{3}{16}$ inch 3 dolerite (Rowley Regis) sand, $\frac{3}{16}$–$\frac{3}{4}$ inch	5,875	2,160	63	1,460	72
1 Portland blast-furnace cement $1\frac{1}{2}$ brick sand, $\frac{3}{16}$ inch 3 broken brick, $\frac{3}{16}$–$\frac{3}{4}$ inch	4,023	1,895	53	2,050	48
1 40 per cent. clinker ($1\frac{1}{2}$ per cent. on 18° sieve) 1 60 per cent. Portland cement $1\frac{1}{2}$ brick sand, $\frac{3}{16}$ inch 3 broken brick, $\frac{3}{16}$–$\frac{3}{4}$ inch	3,147	2,599	17	1,745	44
1 40 per cent. burnt clay 1 60 per cent. Portland cement $1\frac{1}{2}$ brick sand, $\frac{3}{16}$ inch 3 broken brick, $\frac{3}{16}$–$\frac{3}{4}$ inch	3,346	2,011	40	1,840	45
1 Portland blast-furnace cement $1\frac{1}{2}$ crushed sandstone, $\frac{3}{16}$ inch 3 broken sandstone, $\frac{3}{16}$–$\frac{3}{4}$ inch	2,370	1,090	54	580	76
1 Portland cement $1\frac{1}{2}$ crushed sandstone, $\frac{3}{16}$ inch 3 broken sandstone, $\frac{3}{16}$–$\frac{3}{4}$ inch	2,670	1,520	43	700	74
1 Portland cement $1\frac{1}{2}$ clean river sand, $\frac{3}{16}$ inch 3 dolerite (Rowley Regis), $\frac{3}{16}$–$\frac{3}{4}$ inch	3,860	1,430	63	950	75

The first four samples tested had matured for 3 months, the other three for 1 month.

WEIGHT OF CONCRETE

(Per cu. yard; 1 : 2 : 4 mixtures)

	Tons.	Cwts.	Lb.
Brick, broken	1	6	0
Coke breeze	1	0	46
Clinker	1	0	73
Flint	1	15	0
Granite	1	19	0
Gravel (Thames ballast)	1	14	100
Gravel (pit)	1	7	0
Kentish rag	1	18	0
Limestone	1	12	60
Portland stone	1	15	0
Reinforced (average)	1	16	18

CRUSHING STRENGTH OF CONCRETE

Parts by volume.			Lb. per sq. inch.		
Portland cement.	Sand.	Broken stone.	Age. 7 days.	3 months.	6 months.
1	1	3	1,600	3,360	4,300
1	2	4	1,400	2,900	3,700
1	2½	5	1,300	2,670	3,400
1	3	6	1,200	2,440	3,100
1	3½	7	1,100	2,210	2,800
1	4	8	1,000	1,980	2,500
1	5	10	800	1,520	1,900
1	6	12	600	1,060	1,300

Grant found for ballast concrete the crushing strength for 12-inch cubes was:

1 Portland cement, 1 ballast	107 tons
1 Portland cement, 2 ballast	149 tons
1 Portland cement, 5 ballast	89 tons
1 Portland cement, 10 ballast	48 tons

CRUSHING STRENGTH OF PORTLAND CEMENT CONCRETE

(Grant)

Aggregate.	6:1		8		10:1	
	Compressed.	Not compressed.	Compressed.	Not compressed.	Compressed.	Not compressed.
Ballast . . .	81·6	72·8	54	50	42	33
Portland stone .	162·4	120	132	78	88	76
Granite . . .	122	78	78·4	58	62	46
Pottery . . .	115·2	98·4	88	72	74	56
Slag . . .	72	80	78	56	42	34
Flints . . .	82	62	70	56	60	51·2

TESTING FOR MOISTURE IN CONCRETE OR CEMENT FLOORS

Place a piece of paper on the floor and on this some calcium chloride crystals; cover with a tumbler or glass bell and seal with putty. If the floor is damp the crystals will completely disappear within a couple of days. Or place a piece of roofing paper, about 1 yard square, on the floor and leave it for 24 hours, then lift up. Any dampness will show on both floor and paper.

TESTING FOR MOISTURE IN CONCRETE WALLS

Dissolve 1 gramme of phenolphthalein in 99 grammes of absolute alcohol, and keep tightly closed in a glass phial with a drop stopper. It is a colourless fluid. If a few drops are applied to a wall, should the wall be dry the liquid will remain colourless, but should there be any moisture in the cement the alkali will quickly turn the fluid pink.

PAVING BRICKS AND TILES: QUANTITIES

A yard super of paving requires:

Bricks:

Stock bricks (9 × 4½ × 1½ inches, laid flat, with ¼-inch jointing)	36 bricks
Stock bricks (8¾ × 4¼ × 2¾ inches, laid flat, with ½-inch jointing)	32 bricks
Adamantine clinkers (6 × 2½ × 1¼ inches, ½-inch joint)	81 bricks
Dutch clinkers (6¼ × 3 × 1½ inches, in ½-inch joint)	65 bricks
Paving bricks (9 × 4½ × 1¾ inches)	36 bricks
Stocks, laid on edge	45 bricks
Paving bricks, laid on edge	77–85 bricks
Dutch clinkers, laid on edge	140 bricks
Dutch clinkers, herring-bone	136 bricks

Paving Tiles:

12 × 12 inches	9 tiles
10 × 10 inches	13 tiles
6 × 6 inches	36 tiles
4 × 4 inches	81 tiles
3 × 3 inches	144 tiles
6 × 3 inches	72 tiles

PAVING STONE SLABS

Description.	Thickness. Inches.	Weight per foot super in pounds.	1 ton will cover feet super.
York	2	26	86
York	2½	32	70
York	3	39	57½
York	4	52	43
York	6	78	28½
Purbeck	2	27	83
Purbeck	2½	35	66¼
Purbeck	3	40	55¼
Granite	3	41	54½
Granite	4	55	40¾
Granite	6	82	27
Granite	9	123	18

WEIGHTS OF PAVING MATERIALS

Asphalt, fine	137 lb. per cu. foot
Asphalt, coarse	130 lb. per cu. foot
Cement (Portland)	90 lb. per cu. foot
Cement (Portland) and sand (1 : 1)	100 lb. per cu. foot
Cement (Roman)	62 lb. per cu. foot
Cement (Roman) and sand (1 : 1)	85 lb. per cu. foot
Concrete (Portland cement and sand) (1 : 6)	130 lb. per cu. foot
Concrete (Portland cement and sand) (1 : 8)	126 lb. per cu. foot
Cement (lime)	125 lb. per cu. foot
Tar (coal)	63 lb. per cu. foot
York paving	156 lb. per cu. foot

245 9 × 9-inch red quarries equal 1 ton.
833 6 × 6-inch red quarries equal 1 ton.
1,000 6 × 6-inch blue quarries equal 1 ton.

70 feet sup. of 2½-inch York paving and 58 of 3-inch, 68 feet sup. of 2½-inch and 56 feet sup. of 3-inch Purbeck paving, 54 feet sup. of 3-inch and 27 feet sup. of 6-inch granite, and 23 feet sup. of granite kerbs will weigh approximately 1 ton.

STANDARD BUILDING UNITS

Bricks: $2\frac{1}{2} \times 2\frac{3}{4} \times 8$ inches.

Tiles: For load-bearing units: height 8 inches, length 12 inches, widths $3\frac{3}{4}$, 8, 12 inches. For partitions: width 12 inches, length 12 inches, heights 2, 4, 6, 8, 10, 12 inches. Tolerance, not more than 3 per cent. either way of all dimensions.

Blocks: Height $7\frac{3}{4}$ inches, length 15 inches, width of respective sizes 6, 8, 10, 12 inches. Tolerances $\frac{1}{9}$ inch for height, $\frac{1}{8}$ inch for lengths, $\frac{1}{4}$ inch for widths.—*U.S.A. Bureau of Standards.*

COVERING CAPACITY OF MISCELLANEOUS PAVING MATERIAL

1 ton of 5-inch granite pitching will cover $4\frac{1}{4}$ yards sup.; 1 ton of 6×7-inch granite paving will cover $3\frac{3}{4}$ yards sup.; 1 ton 9-inch granite paving will cover $2\frac{1}{2}$ yards sup.; 1 ton pebble paving will cover 4–$4\frac{1}{2}$ sq. yards; 1 ton ragstone from 5 to $5\frac{1}{2}$ sq. yards.

V. ROOFS, FLOORS, AND PARTITIONS

HOW TO ASCERTAIN RAFTER LENGTHS AND BEVELS

Draw a roof to scale, as in accompanying figure. For lengths and cuts of common rafters halve the line *ab*, and from *c* extend a line out-

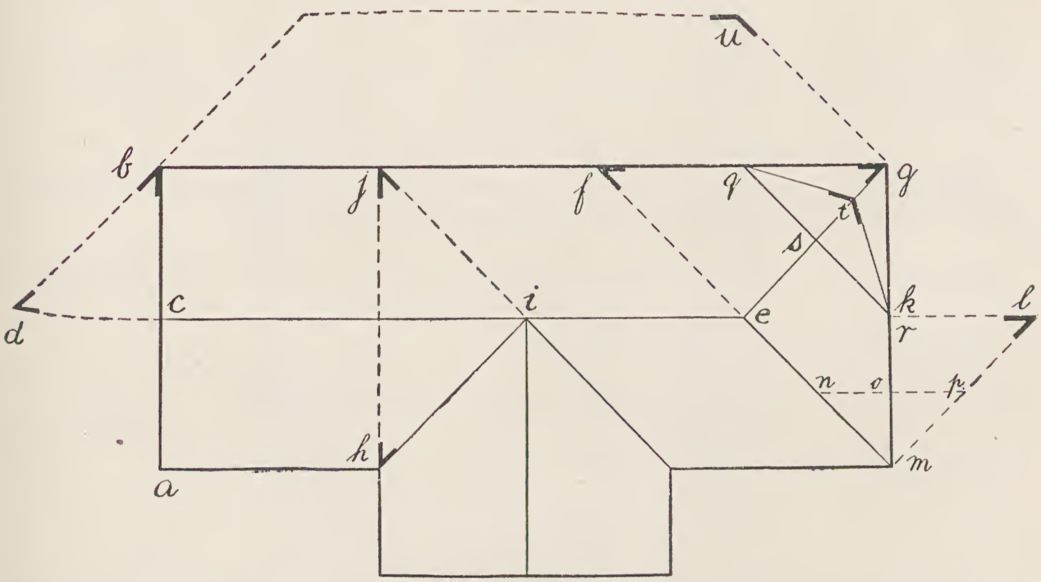

Fig. 148.—Rafter lengths and cuts

wards to the height of ridge to *d*; join *b* to *d*, the angle at *b* will give the foot cut and at *d* the plumb cut. The length is found by scaling. For hip rafters extend inwards a line from *e* to *f* equal to the height of the ridge, join *f* to *g*; the angles at *fg* give the plumb and foot cuts. The length

of the rafters is formed by scaling. The lengths and cuts for the valley rafter *hi* are the same as for the hip rafter, and are found as shown at *ij* and *ih*. For jack rafters extend a line outward from *k* to *l* and join *l* to *m*, and the angle at *l* will give the cheek cut. Foot and plumb as for common rafters. For length of jack rafter at *no* extend a line to *p*. Others are obtained by scaling. For backing of hips extend a line at right angles to *eg*, cutting the eaves lines at *qr* and the line *eg* at *s*, which is taken as a centre and a radius equal to the perpendicular distance from *s* to the line *fg*; then strike an arc to *t*. Complete triangle *qrt*, and the angle at *t* will give the backing of the hip. For bevel of roof boarding extend lines at side to true length of the common rafters and the bevel cuts will be shown at *u*.

FORMULAE FOR ROOF SCANTLINGS

(After Hurst)

a = area of section in inches.
b = breadth in inches.
d = depth in inches.
L = length of piece in feet.
S = span of roof.

Pitch 27°–45°.

King Post: $a = S^2 \times 0{\cdot}03$ for pine or by $0{\cdot}033$ for oak.

$$b = \frac{a}{d}$$

$$d = \frac{a}{b}$$

Queen Post: $a = p^2 \times 0{\cdot}135$ for pine or $0{\cdot}16$ for oak, p being length in feet of that part of tie beam supported by queen post.

Tie beam: $d = \dfrac{L}{\sqrt[3]{b}} \times 1{\cdot}47$ for pine, or $1{\cdot}52$ for oak.

Principal rafters in King Post Truss:

$$bd = \frac{S^2T}{40R} = \text{sectional area in sq. inches.}$$

Principal rafters in Queen Post Truss:

$$bd = \frac{S^2T}{40R}.$$

In above T is the distance apart of the trusses and R the rise of the roof, both in feet.

Straining beam: depth should be to thickness as 10 is to 7.

$$d = \sqrt{LS\tfrac{1}{2}} \times 0{\cdot}9 \text{ for pine.}$$
$$b = 0{\cdot}7d.$$

Struts and braces:

$$d = \sqrt{Lp\tfrac{1}{2}} \times 0{\cdot}8 \text{ for pine.}$$
$$b = 0{\cdot}6d.$$

p being length in feet of that part of principal rafter supported by strut.

Purlins:

$$d = \sqrt[4]{L^3C} \text{ for pine, or } \times 1{\cdot}04 \text{ for oak.}$$
$$b = 0{\cdot}6d.$$
$$C = \text{distance in feet between purlins.}$$

Common rafters: $d = \dfrac{L}{6\frac{1}{3}} \times 0{\cdot}72$ for pine, or $0{\cdot}74$ for oak.

If common rafters are 2 inches thick, then $d = {\cdot}571L$ for pine. Usually trusses are built with members all of equal width.

IRON STRAPS

Longest unsupported part of tie beam. Feet.	Size of straps. Inches.
10	$1 \times \frac{3}{16}$
15	$1 \times \frac{1}{2}$
20	$2 \times \frac{1}{2}$

Straps at the feet of principal rafters should be of same section as that for supporting tie beam. Both should be *twice* the net sectional area of the strap.

KING AND QUEEN RODS

When King and Queen iron or steel rods are used in composite roof, the following formula should be adopted to arrive at safe strain in tension;

$$\frac{\text{Total load} \times \text{span}}{\text{Rise of roof} \times 8} = \text{tension in pounds.}$$

LENGTHENING TIMBER: SAFE JOINTS

Flitched girders:

$$w = \frac{d^2}{L}(Cb \times 30t);$$

where w = breaking weight in cwts.; b = breadth of timber in inches; d = depth of timber in inches; L = length in feet; t = thickness of iron flitch; C = co-efficient of safety (*see* table below).

C = 4·0 for teak.
3·7 for oak (English or Baltic).
3·2 for oak (Canadian).
3·0 for northern pine.
2·8 American pine or spruce fir.
2·2 elm.

Scarfed joint; length of scarf in proportion to depth of tie (Tredgold):

Hardwood	6 (without bolts)	3 (with bolts)	2 (with bolts and indents)
Softwood	12 (without bolts)	6 (with bolts)	4 (with bolts and indents)

To Ascertain Breaking Strain of a Rectangular Wooden Beam:

$$w = \frac{c \times d \times b^2}{l}$$

where w = weight in cwts.; d = depth; b = breadth; c = a constant for the particular wood.

The constant for the breaking strain of a firm beam with weight in centre, 4, with weight distributed, 8.

ROOF SCANTLINGS: IRON TRUSSES

(Molesworth)

Span in feet.	Rafter T-iron. Inches.	A. Inches diameter.	B. Inches diameter.	C. Inches diameter.
20	$2\frac{1}{2} \times 2 \times \frac{3}{8}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{5}{8}$
25	$2\frac{3}{4} \times 2 \times \frac{3}{8}$	$\frac{3}{4}$	1	$\frac{3}{4}$
30	$2\frac{3}{4} \times 2\frac{1}{2} \times \frac{1}{2}$	$2\frac{1}{4} \times \frac{1}{4}$	$2\frac{1}{4} \times \frac{3}{8}$	$2\frac{1}{4} \times \frac{1}{4}$
35	$3 \times 2\frac{3}{4} \times \frac{1}{2}$	$2\frac{1}{2} \times \frac{5}{16}$	$2\frac{1}{2} \times \frac{1}{2}$	$2\frac{1}{2} \times \frac{5}{16}$
40	$3\frac{1}{2} \times 3 \times \frac{1}{2}$	$2\frac{1}{2} \times \frac{5}{8}$	$2\frac{1}{2} \times \frac{5}{8}$	$2\frac{1}{2} \times \frac{3}{8}$
45	$4 \times 3 \times \frac{1}{2}$	$3 \times \frac{3}{8}$	$3 \times \frac{1}{2}$	$3 \times \frac{3}{8}$

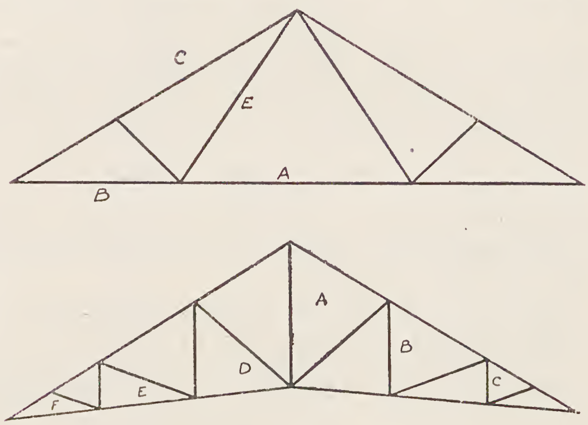

Fig. 149.—Iron roof struts.

ROOF SCANTLINGS: STEEL

Span in feet.	Rafter. T-iron. Inches.	Struts. T-iron. Inches.	King and Queen Bolts. Inches diameter.			Tie Rods. Inches diameter.		
			A.	B.	C.	D.	E.	F.
20	$2\frac{1}{2} \times 2 \times \frac{3}{8}$	$2 \times 2 \times \frac{3}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	—	$\frac{5}{8}$	$\frac{3}{4}$	—
25	$2\frac{3}{4} \times 2\frac{1}{2} \times \frac{3}{8}$	$2 \times 2 \times \frac{3}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{7}{8}$	1	—
30	$2\frac{3}{4} \times 2\frac{1}{2} \times \frac{1}{2}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	1	$\frac{3}{4}$	$\frac{5}{8}$	1	$1\frac{1}{8}$	—
35	$3 \times 2\frac{3}{4} \times 1\frac{1}{2}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	1	$\frac{3}{4}$	$\frac{3}{4}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
40	$3\frac{1}{2} \times 3 \times \frac{1}{2}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{8}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$
45	$4 \times 3\frac{1}{2} \times \frac{1}{2}$	$3 \times 3 \times \frac{1}{2}$	$1\frac{1}{4}$	1	$\frac{7}{8}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$
50	$4 \times 3\frac{1}{2} \times \frac{5}{8}$	$3 \times 3 \times \frac{5}{8}$	$1\frac{3}{4}$	1	$\frac{7}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$
55	$5 \times 4\frac{1}{2} \times \frac{5}{8}$	$4 \times 4 \times \frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{8}$	1	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$
60	$5 \times 4\frac{1}{2} \times \frac{3}{4}$	$4 \times 4 \times \frac{5}{8}$	$1\frac{3}{8}$	$1\frac{1}{8}$	1	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$

Trusses in first table 6 feet apart; in second 6 feet 8 inches apart. Rise (apex) for both = $\frac{1}{6}$ of span. Rise of tie end $\frac{1}{30}$ of span and $\frac{1}{4}$ of span respectively.

KING POST TRUSSES

Span in feet.	Tie Beam. Inches.	King Post. Inches.	Principal Rafters. Inches.	Struts. Inches.	Purlins Inches.	Common Rafters Inches
20	8 × 3–9 × 4	3 × 3–4 × 3	4 × 3–4 × 4	3 × 3–4 × 2½	7 × 3–8¼ × 4¾	3 × 2–3½ × 2
22	8 × 4–9½ × 5	4 × 3–5 × 3½	4 × 4–5 × 4	4 × 3–3½ × 2¼	7 × 4–8¼ × 5	3½ × 2–3¾ × 2
24	10 × 5	5 × 3½	5 × 4	3¾ × 2½	8½ × 5	4 × 2
26	9 × 4–10½ × 5	4 × 4–5 × 4	4½ × 4–5 × 4¼	4 × 4–4½ × 2¾	7 × 4–8¾ × 5	4 × 2–4¼ × 2
28	11 × 6	6 × 4¼	6 × 4	4½ × 3	9 × 5¼	4½ × 2
30	11 × 4–11½ × 6	6 × 4–6 × 4½	6 × 4	4½ × 4–5 × 3	8 × 4–9 × 5½	4½ × 2

Principals placed 10 feet apart.

In this table the data of two authorities are given, using for first set of figures American pine, for second Northern pine.

QUEEN POST TRUSSES

Span in feet.	Tie Beam Inches.	Queen Post. Inches.	Principal Rafters. Inches	Straining Seam. Inches.	Struts Inches	Purlins Inches.	Common Rafters. Inches.	Straining Sill. Inches.
32	10 × 5	5 × 3½	5 × 6½	6½ × 5	4 × 2¼	8¼ × 4¾	4½ × 2	3 × 3
34	9 × 4–10¼ × 5	4 × 4–5 × 5¾	4½ × 4–5 × 6½	7 × 4–6¾ × 5	4 × 4–4¼ × 2¼	7 × 4–8¾ × 5	3 × 2–4½ × 2	4 × 3
36	10½ × 5	5 × 4	5 × 6¾	7 × 5	4¼ × 2½	8½ × 5	4½ × 2	4 × 3
38	9 × 4–10 × 6	4½ × 4–6 × 3¾	5 × 4–6 × 6	8 × 4–7 × 6	4½ × 4–4½ × 2½	7 × 4–8½ × 5	4 × 2–4½ × 2	4 × 3
40	11 × 6	6 × 4	6 × 6¼	8 × 6	4½ × 2¾	8¾ × 5	4¾ × 2	4 × 3
42	11 × 4–11½ × 6	5 × 4–6 × 4½	6 × 4–6 × 6½	8 × 4–8¼ × 6	5 × 4–4½ × 2¾	8 × 4–9 × 5	4½ × 2–4¾ × 2	4 × 3
44	11 × 5	6 × 5	6 × 5	9 × 5	5 × 5	8 × 4	5 × 2	4 × 3
45	12 × 6	6 × 5	6 × 7	3½ × 6	4½ × 3	9 × 5	5 × 2	4 × 3

Principals 10 feet apart. On this table data of two authorities are given, as in table above.

MANSARD ROOF

Lower Truss

Span in feet	Tie Beam. Inches.	Principal Rafters. Inches.	Queen Post. Inches.	Curbs Inches.
22	11 × 4	6 × 4	6 × 4	4 × 4
26	11 × 4	7 × 4	7 × 4	5 × 4
30	12 × 5	7 × 5	5 × 5	5 × 4

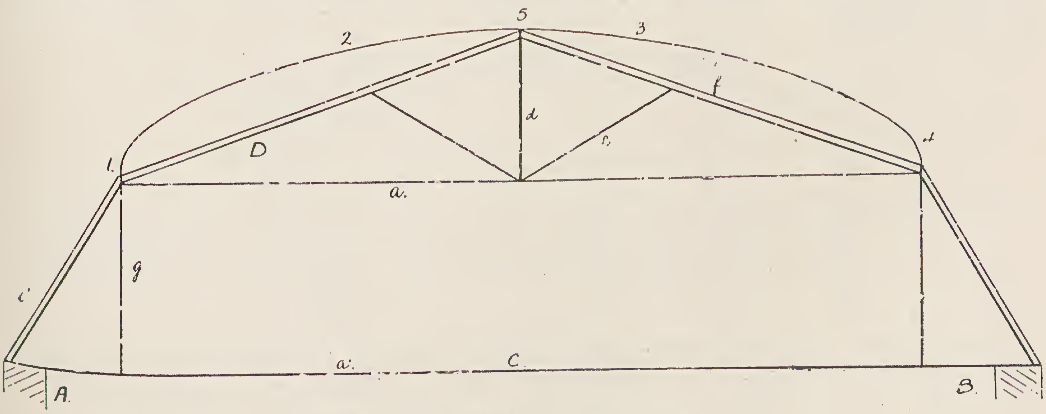

Fig. 150 – Struts for Mansard roof.

UPPER TRUSS

Span in feet.	Tie Beam. Inches.	Principal Rafters. Inches.	Common Rafters. Inches.	King Post. Inches.	Struts. Inches.
22	8 × 4	4 × 3	3 × 2	3 × 3	3 × 3
26	9 × 4	4 × 4	$3\frac{1}{2}$ × 2	4 × 3	4 × 3
30	11 × 4	$4\frac{1}{2}$ × 4	4 × 2	4 × 4	4 × 4

To determine the pitch, with point C as centre and a radius equal to half the span AB, a semicircle is described, which is divided into four parts at points 1, 2, 3, 4, and also bisected at point 5. The line A1 and B4 will give the pitch of the steep portions of the roof, the flat pitch being given by the lines 1–5 and 4–5.

BELFAST TRUSS

(BOWSTRUNG TRUSS)

Span.	Strings or Ties. Inches.	Bows or Ribs. Inches.	Bars or Struts. Inches.	Purlins (maximum centres 2 ft. 6 in.). Inches
20 . .	$4\frac{1}{2} \times \frac{3}{4}$	$1\frac{1}{2} \times \frac{3}{4}$	$2\frac{1}{2} \times \frac{3}{4}$	3 × 2
25 . .	$6 \times \frac{3}{4}$	$2 \times \frac{3}{4}$	$2\frac{3}{4} \times \frac{3}{4}$	$3\frac{1}{2}$ × 2
30 . .	7 × 1	2 × 1	$3 \times \frac{3}{4}$	$3\frac{1}{2}$ × 2
40 . .	$8 \times 1\frac{1}{4}$	$2 \times 1\frac{1}{4}$	$3 \times \frac{7}{8}$	4 × 2
50 . .	$9 \times 1\frac{1}{4}$	$2\frac{1}{4} \times 1\frac{1}{4}$	$3 \times \frac{7}{8}$	4 × 2
60 . .	$10 \times 1\frac{1}{2}$	$2\frac{1}{4} \times 1\frac{1}{2}$	$3\frac{1}{2}$ × 1	4 × 2
70 . .	$11 \times 1\frac{1}{2}$	$3 \times 1\frac{1}{2}$	4 × 1	$4\frac{1}{2}$ × 2

Principals placed not more than 10 feet centres. Suitable wind bracing to be provided.

WIND PRESSURE

Wind pressure varies greatly according to season and situation. A "fresh breeze," travelling at 15 miles per hour, exerts a pressure of just over 1 pound per sq. foot, a "strong breeze," 20 miles per hour, nearly 2 pounds; a "storm," 60 miles per hour, nearly 18 pounds; a "hurricane," 80 miles per hour, $31\frac{1}{2}$ pounds. The wind pressure increases with the height of the building. Forty-pound pressure is taken as the factor in this country.

WIND PRESSURE ON ROOFS

Angle of slope.	Pressure normal (40 pounds per sq. foot) to surface of roof. Pounds per sq. foot.
5°	5·0
10°	9·6
20°	18·0
26° 34′	23·6
30°	26·4
46°	33·2
45°	36·1
50°	38·0
60°	40·0

The weight of snow is assumed to be from 5 to 12 pounds per sq. foot, but need not be taken into account if proper allowance is made for wind pressure; but on a flat roof provision must be made for removal.

WEIGHT OF ROOFS AND ROOFING

	Pounds.
Wood trusses, King Post, 20-foot span	390
Wood trusses, King Post, 30-foot span	1,020
Wood trusses, Queen Post, 40-foot span	1,460
Wood trusses, Queen Post, 50-foot span	2,230
Wood trusses, Queen Post, 60-foot span	3,640
Purlins and rafters	per foot sup. 7
Deal boarding	per foot sup. ·85
Iron trusses, 20-foot span	each 220–270
Iron trusses, 30-foot span	each 480–620
Iron trusses, 40-foot span	each 840–1,135
Iron trusses, 50 foot-span	each 1,800
Iron trusses, 60-foot span	each 3,000
Slating, Comtesses, 3-inch lap	per foot sup. 11
Tiling, plain, 3½-inch lap	per foot sup. 16·25–18
Tiling, plain, 4-inch lap	per foot sup. 14·0–14·5
Tiling, pan, 3-inch lap	per foot sup. 12·32–12·9
Corrugated iron, 24 gauge	per foot sup. 1·4
Corrugated iron, 18 gauge	per foot sup. 2·8
Zinc	per foot sup. 1·5
Copper	per foot sup. 1·0
Lead, 6-pound	per foot. sup 9·5
Lead, 7-pound	per foot sup. 11·2
Asbestos roofing (about)	per foot sup. 2·25
Shingles, cedar	per foot sup. 3·0
Shingles, oak	per foot sup. 4·0

FORMULAE : FLOORS

b = breadth in inches. d = depth in inches. L = length in feet.
Wood girders, 10 feet apart in floors :

$$d = \sqrt[3]{\frac{L^2}{6}} \times 4{\cdot}2 \text{ for pine ; } \times 4{\cdot}34 \text{ for oak.}$$

$$b = \frac{L^2}{d^3} \times 74 \text{ for pine ; } \times 82 \text{ for oak.}$$

To obtain maximum stiffness $b = \frac{5}{7}d$.

Bearing on walls of 9–12 inches, in accordance with length of girder. Ends must be built in, space being left for ventilation. Binding joists, 6 feet apart :

$$d = \sqrt[3]{\frac{L^2}{6}} \times 3{\cdot}42 \text{ for pine ; } \times 3{\cdot}53 \text{ for oak.}$$

$$b = \frac{L^2}{d^3} \times 40 \text{ for pine ; } \times 44 \text{ for oak.}$$

Binding joists carrying ceiling only can be replaced by ceiling joists, multiplying by 1·2 or 1·25 instead of 0·64 or 0·67 (*see* below).

Bridging or single joists 12 inches from centre to centre :

$$d = \sqrt[3]{\frac{L^2}{6}} \times 2{\cdot}2 \text{ for pine ; } \times 2{\cdot}3 \text{ for oak.}$$

Trimming joists as single joists, plus ⅛ inch in width for every joist they carry.

Single joists over 8 feet in span should be straddled.
Ceiling joists, 12 inches centre to centre :

$$d \doteq \frac{L}{\sqrt[2]{6}} \times 0{\cdot}64 \text{ for pine ; } \times 0{\cdot}67 \text{ for oak.}$$

PART II.—DEAD AND IMPOSED LOAD

(L.C.C. By-laws, 1952)

" **2.01** (1). *Dead Load.*—In calculating dead load, the unit weights of the materials shall be deemed to be those specified in the appropriate provisions of B.S. 648 : 1949 in the case of material therein mentioned (unless ascertained to the satisfaction of the district surveyor to be otherwise), and, in the case of any other materials, such unit weights as may be ascertained to the satisfaction of the district surveyor.

" (2) The dead load of any partitions whereof the positions are not definitely located in the design of the building, shall be deemed to be a uniformly distributed load per square foot of the floor or part of a floor on which the partitions are to be erected of 10 per cent. of the estimated dead weight per foot run of those partitions but not less than 20 lb. per square foot if that floor or part of a floor is used for office purposes.

" **2.02** (1). *Imposed Load.*—In all cases the imposed loads to be provided for shall be ascertained to the satisfaction of the district surveyor, but, subject to the provisions of this by-law, the minimum imposed loads for the floors, roofs, stairs and landings of the types specified in Table I, and for slabs forming part of, and for beams supporting such floors, roofs, stairs and landings, shall be either

" (*a*) the loads specified in the third column of that Table ; or

" (*b*) except for cantilever beams and cantilever slabs, the loads specified in the fourth column or the fifth column (as the case may be) of that Table ; or

" (*c*) the imposed loads as ascertained to the satisfaction of the district surveyor ;

whichever shall be the heaviest :

" provided that, for the purpose of ascertaining the reactions to be allowed for in calculating the loads on columns, piers, walls or foundations, the minimum imposed loads shall be either the loads specified in the third column of Table I or the imposed loads as ascertained to the satisfaction of the district surveyor, whichever shall be the heavier.

TABLE I

MINIMUM IMPOSED LOADS

Class No.	Types of floors.	lb. per sq. ft. of floor area.	Slabs. lb. uniformly distributed over the span per ft. width.	Beams. lb. uniformly distributed over span.
(1)	(2)	(3)	(4)	(5)
	(In this Table, a reference to a floor includes a reference to any part of that floor to be used as a corridor and " Slabs " includes beams and ribs spaced not farther apart than 3 feet between centres, and " Beams " means all other beams and ribs.)			
1	Floors in dwelling houses of not more than two storeys, in one occupation.	30	240	1,920
2	Floors (other than those of Class No. 1) for residential purposes including tenements ; floors in hospital wards, bedrooms and private sitting-rooms in hotels, dormitories.	40	320	2,560
3	Office floors above the entrance floor ; floors of workrooms without central power-driven machines and storage.	50	400	3,200
4	Office entrance floors and office floors below the entrance floor ; floors of classrooms in schools.	60	480	3,840
5	Floors of retail shops for display and sale of merchandise ; floors of workrooms with central power-driven machines ; floors of garages for vehicles not exceeding 2½ tons gross weight.	80	640	5,120
6	Floors of warehouses, workshops, factories and other buildings or parts of buildings of similar category for light weight loads ; office floors for storage and filing purposes.	100	800	6,400
7	Floors of warehouses, workshops, factories and other buildings or parts of buildings of similar category for medium weight loads ; floors of garages for vehicles not exceeding 4 tons gross weight.	150	For garage floors only, 1·5 × maximum wheel load or 2,000 lb. whichever is the greater, considered to be distributed over a floor area 2 ft. 6 in. square.	
8	Floors of warehouses, workshops, factories and other buildings or parts of buildings of similar category for heavy weight loads ; floors of bookstores and stationery stores.	200	—	—
	Types of roofs.	**lb. per sq. ft. of covered area measured horizontally.**		
9	Flat roofs :			
	(*a*) Where no access is provided to the roof (other than such access as may be necessary for cleaning and repair works).	15	—	—
	(*b*) Where access (in addition to such access as may be necessary for cleaning and repair works) is provided to the roof.	30	240	1,920
10	Pitched roofs (where no access is provided to the roof) having an inclination to the horizontal			
	(*a*) of 30 degrees or less	15 (vert.)	—	—
	(*b*) of 75 degrees or more	NIL	—	—
	For roof slopes between 30 degrees and 75 degrees, the imposed load shall be determined by interpolation.			

TABLE I—*continued.*

Class No.	Types of floors.	lb. per sq. ft. of floor area.	Slabs. lb. uniformly distributed over the span per ft. width.	Beams. lb. uniformly distributed over span.
(1)	(2)	(3)	(4)	(5)
	Types of stairs and landings and cantilever access balconies.	lb. per sq. ft. of area measured horizontally.		
11	(*a*) Used in connection with floors of Class No. 1	30	—	—
	(*b*) Used in connection with floors of Classes No. 2, No. 3 or No. 4	60	—	—
	(*c*) Used in connection with floors of any other classes	100	—	—

FIBREBOARDS

Type.	Length. ft.	Width. ft.	Thickness. ft.
Insulating board, low density	8, 10, 12	4 and 6	$\frac{5}{16}$, $\frac{3}{8}$, $\frac{1}{2}$
Wallboards, medium density	8, 12, 16	4 and 5	$\frac{3}{16}$, $\frac{1}{4}$
Hardboard and Super-hardboard	8, 12, 16	4 and 5	$\frac{1}{8}$, $\frac{3}{16}$

SCANTLINGS FOR PARTITIONS

Members.	Common partitions. Inches.	Double framed. Inches.
Heads	3 × 2	6 × 3
Sills	3 × 2	6 × 3
Inter-ties	—	6 × 3
Braces	—	4 × 3
Door posts	3 × 2 3 × 2	— —
Uprights	—	4 × 3
Studs	3 × 2	4 × 2

A square (100 sq. feet) of partitioning weighs from 1,000 to 2,000 lb.

VI. METALS

EXPANSION OF METALS

Between 32° F. and 212° F.

Cast iron	1 part in 889
Wrought iron	1 part in 819
Iron wire	1 part in 812
Steel, tempered	1 part in 807
Steel, untempered	1 part in 927
Lead	1 part in 349
Copper	1 part in 581
Zinc	1 part in 340
Brass	1 part in 532

TO DETERMINE ELONGATION OF IRON AND STEEL

Co-efficients of expansion per degree F.: cast iron = ·0000059; wrought iron = ·0000069; mild steel = ·0000065.

Length at any temperature may be calculated by the following formula:

$$L = l + la(T - t),$$

where L = length at normal temperature (T); l = length at time of experiment; t = temperature at time of testing; a = co-efficient as given above.

METAL GAUGE THICKNESSES

British Standard Gauge No.	Diameter of thickness.		British Standard Gauge No.	Diameter of thickness.	
	Inch.	Mm.		Inch.	Mm.
0000000	·5	12·7	10	·128	3·251
000000	·464	11·785	11	·116	2·946
00000	·432	10·97	12	·104	2·641
0000	·4	10·16	13	·092	2·337
000	·372	9·448	14	·08	2·032
00	·348	8·839	15	·072	1·828
0	·324	8·229	16	·064	1·625
1	·3	7·62	17	·056	1·422
2	·276	7·01	18	·048	1·219
3	·252	6·4	19	·04	1·016
4	·232	5·893	20	·036	·914
5	·212	5·385	21	·032	·812
6	·192	4·877	22	·028	·711
7	·176	4·47	23	·024	·609
8	·16	4·064	24	·022	·559
9	·144	3·657	25	·02	·508

GALVANISED CORRUGATED SHEET IRON

Wire gauge.	Approximate weight per sheet.					
	5 feet long. Lb.	6 feet long. Lb.	7 feet long. Lb.	8 feet long. Lb.	9 feet long. Lb	10 feet long. Lb.
16	33½	40	47	53½	66	67
18	26½	32	37	43	48	53
20	21	25½	30	34	38	42½
22	17	20	23½	27	30	33½
24	13¼	16	18¾	21½	24	27
26	10¼	12¼	14½	16½	18¾	21
28	9½	11¼	13¼	15	17	19

AREA COVERED BY TON OF CORRUGATED SHEETS

(With allowance for laps)

Gauge	16	18	20	22	24	26	28
Sq. feet . .	600	800	1,020	1,280	1,530	2,100	2,250

WIRE GAUGES

British Standard Gauge.		Birmingham Gauge.		American Gauge (also known as Browne and Sharpe Gauge).	
No. S.W.G.	Diameter in inch.	No. B.W.G	Diameter in inch.	No. A.W.G.	Diameter in inch.
0000000	·500	—	—	—	—
000000	·464	0000	·454	0000	·4600
00000	·432	000	425	—	—
0000	·400	—	—	000	·4096
000	·372	00	·380	00	·3648
00	·348	0	·340	—	—
0	·324	—	—	0	·3249
1	·300 ($\frac{5}{16}$)	1	·300 ($\frac{5}{16}$)	—	—
2	·276	2	·284	1	·2893 ($\frac{5}{16}$)
3	·252 ($\frac{1}{4}$)	3	·259 ($\frac{1}{4}$)	2	·2576 ($\frac{1}{4}$)
4	·232	4	·233	3	·2294
5	·212	5	·220	—	—
6	192	6	·208	4	·2043
7	·176 ($\frac{3}{16}$)	7	·180 ($\frac{3}{16}$)	5	·1819
8	·160	8	·165	6	·1620
9	·144	9	·148	7	·1443
10	·128	10	·134	8	·1285 ($\frac{1}{8}$)
11	·116 ($\frac{1}{8}$)	11	·120 ($\frac{1}{8}$)	9	·1144
12	·104	12	·100	10	·1019
13	092 ($\frac{1}{10}$)	13	·095 ($\frac{1}{10}$)	11	·1007
14	·080	14	·083	12	·0808
15	·072	15	·072	13	·0720
16	·064 ($\frac{1}{16}$)	16	·065 ($\frac{1}{16}$)	14	·0641 ($\frac{1}{16}$)
17	·056	17	·058	15	·0571
18	·048 ($\frac{1}{20}$)	18	·049 ($\frac{1}{20}$)	16	·0508
—	—	—	—	17	·0453
19	·040	19	·042	18	·0409
20	·036	20	·035	19	·0359
21	·032	21	·032	20	·0320
22	·028 ($\frac{1}{32}$)	22	·025 ($\frac{1}{32}$)	21	·0285
23	·024	23	·025	22	·0253
24	·022 ($\frac{1}{40}$)	24	·022 ($\frac{1}{40}$)	23	·0226
25	·020	25	·020	24	·0201
26	·018	26	·018	25	·0179
27	·0164	27	·016	26	·0159
28	·0148	28	·014	27	·0142
29	·0136	29	·013	—	—
30	·0124 ($\frac{1}{64}$)	30	·012 ($\frac{1}{64}$)	28	·0126 ($\frac{1}{64}$)

SAFE LOADS IN TONS FOR SMALL WROUGHT-IRON STRUTS

Cross-section of angles or tees (inches).	Length in feet.					
	3	4	6	8	10	12
$2 \times 2 \times \frac{1}{2}$	2·18	2·0	1·4	1·05	0·9	0·6
$2 \times 2 \times \frac{3}{8}$	3·0	2·6	2·35	1·45	1·08	0·82
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	2·71	2·43	1·93	1·43	1·14	0·85
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	4·0	3·55	2·81	2·10	1·65	1·24
$3 \times 3 \times \frac{1}{4}$	3·5	3·26	2·77	2·25	1·86	1·50
$3 \times 3 \times \frac{3}{8}$	5·1	4·83	4·09	3·33	2·78	2·22
$3 \times 3 \times \frac{1}{2}$	6·7	6·26	5·31	4·38	3·61	2·9
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{4}$	4·21	4·0	3·33	2·66	2·21	1·76
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8}$	6·15	5·85	5·03	4·22	3·56	2·9
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$	8·10	7·54	6·74	5·8	4·9	4·04
$4 \times 4 \times \frac{3}{8}$	7·24	7·0	6·32	5·52	4·81	4·1
$4 \times 4 \times \frac{1}{2}$	9·28	9·0	8·06	7·22	6·26	5·35
$4 \times 4 \times \frac{5}{8}$	11·7	11·2	10·6	8·9	7·75	6·43

Factor of safety 6, ends fixed.

GAUGE AND WEIGHT OF SHEET COPPER

Birmingham wire gauge.	Weight per sq. foot Lb.	oz.	Birmingham wire gauge.	Weight per sq. foot. Lb.	oz.	Birmingham wire gauge.	Weight per sq. foot Lb.	oz.
1	14	0	11	5	10	21	1	8
2	13	0	12	5	0	22	1	6
3	12	0	13	4	8	23	1	2
4	11	0	14	4	0	24	1	0
5	10	2	15	3	8	25	0	14
6	9	4	16	3	0	26	0	12
7	8	8	17	2	10	27	0	11
8	7	12	18	2	4	28	0	10
9	7	0	19	2	0	29	0	9
10	6	4	20	1	12	30	0	8

SHEET LEAD

Appropriate Weight for Different Work

	Per square foot
Roofs, flats, main gutters	8–7
Hips, ridges, and small gutters	6
Flashings	5
Cisterns	7
Sink bottoms	8
Sink sides	6
Rain-water pipes	7

FORMULAE FOR PIPES

$$t = \frac{p \times r \times f}{T}.$$

where t = thickness of pipes in inches; p = internal pressure of pipe in sq. inches; r = radius of pipe in inches; T = tensile strength of metal per sq. inch; f = factor of safety.

Factor of safety:

$$p = \frac{t \times T}{r \times f}$$

Bursting pressure $= \dfrac{t \times T}{r}$

Values of f:

Cast iron = 9
Wrought iron = 6
Copper = 6
Lead = 12

To find weight of pipes per foot:

Let w = weight in pounds per lineal foot of pipe
D = external diameter of pipes in inches
d = internal diameter of pipes in inches

Wrought-iron pipes $w = (D^2 \times 2{\cdot}64) - (d^2 \times 2{\cdot}64)$
Cast-iron pipes $w = (D^2 \times 2{\cdot}48) - (d^2 \times 2{\cdot}48)$
Copper pipes $w = (D^2 \times 3{\cdot}02) - (d^2 \times 3{\cdot}02)$
Lead pipes $w = (D^2 \times 3{\cdot}87) - (d^2 \times 3{\cdot}87)$

WEIGHT OF LEAD SERVICE PIPES

Internal diameter. Inches.	Weight per yard. Pounds.
½	6–7
¾	9–11
1	12–16
1¼	16–21
1½	21–28

WEIGHT OF CAST-IRON PIPES

Pounds per Lineal Foot. Thickness in Inches.

Bore.	⅜	½	⅝	¾	⅞	1	1⅛	1¼
2	8·7	12·3	16·1	20·2	24·7	29·4	34·5	—
2½	10·6	14·7	19·2	23·9	29	34·4	40	46
3	12·4	17·2	22·2	27·6	33·3	39·3	45·6	52·2
3½	14·2	19·6	25·3	31·3	37·6	44·2	51·1	58·2
4	16·1	22·1	28·4	35	41·9	49·1	56·6	64·4
4½	18·0	24·5	31·6	38·6	46·2	54	62·1	70·5
5	19·8	27	34·5	42·3	50·5	58·9	67·6	76·7
5½	21·6	29·4	37·6	46	54·8	63·8	73·2	82·8
6	23·5	31·9	40·6	49·7	59·1	68·7	78·7	88·7
6½	25·3	34·4	43·7	53·4	63·4	73·4	84·2	95·1
7	27·1	36·8	46·8	56·8	67·6	78·5	89·7	101·2
7½	29	39·0	49·9	60·7	71·9	83·4	95·3	107·4
8	30·8	41·7	52·9	64·4	76·2	88·3	100·8	113·5
8½	32·9	44·4	56·2	68·3	80·8	93·3	106·5	119·9
9	34·5	46·6	59·1	71·8	84·8	98·2	111·8	125·8
9½	36·4	49·1	62·1	75·5	89·1	103·1	117·4	131·9
10	38·2	51·5	65·2	79·2	93·4	108	122·9	144·2
10½	40	54	68·3	82·8	97·7	112·9	128·4	150·3
11	41·9	56·5	71·3	86·5	102	117·8	133·9	156·4
11½	43·7	58·9	74·4	90·2	106·3	122·7	139·4	162·6
12	45·5	61·3	77·5	93·6	110·6	127·6	145	174·6
13	49·1	66·1	83·4	101·1	119	137·2	155·7	186·8
14	52·8	71	89·6	108·4	127·6	147	166·8	199·1
15	56·5	75·9	95·7	115·8	136·1	156·8	177·8	211·3
16	60·2	86·8	101·8	123·1	144·7	160·6	188·8	223·6
17	63·8	85·7	108	130·5	153·3	176·4	199·8	235·8
18	67·5	90·6	114·1	137·8	161·9	186·2	210·9	248·1
19	71·2	95·5	120·2	145·2	170·4	196	221·9	260·3
20	74·9	100·5	126·3	152·5	179	205·8	232·9	272·6
21	78·5	105·4	132·5	159·9	187·6	215·6	243·1	284·8
22	82·2	110·3	138·6	167·2	196·2	225·4	255	297·1
23	85·9	115·2	144·7	174·6	204·7	235·2	266	309·3
24	89·6	120·1	150·8	181·9	213·3	245	277	

VII. WATER SUPPLY AND HYDRAULICS

WATER QUANTITIES

1 pint	= 34·65 cu. inches	= 1¼ pounds.
1 quart	= 69·31 cu. inches	= 2½ pounds.
1 gallon	= 277½ cu. inches	= 10 pounds.
1 bushel	= 2,218½ cu. inches	= 80 pounds.
1 cu. inch		= ·0361 pound.
1 cu. foot	= 1,728 cu. inches	= 62·35 pounds = 6·23 gals.
1 cu. yard	= 168,268 gals.	
1 ton of water	= 35·76 cu. feet	= 224 gals.

1 gal. of water will fill a receptacle 6 × 6 × 7¾ inches.
1 quart of water will fill a receptacle 4 × 4 × 4½ inches.

A cylinder to contain a gallon of water for every inch in height should be 18·78933 inches in diameter.

Water occupies least space when at 39° F.

A column of water 1 foot high = ·434 pound pressure per sq. inch.

Head of water in feet × 62·35 = pressure in pounds per sq. foot of surface.

Head of water in feet × ·434 = pressure in pounds per sq. inch.

Head of water in feet ÷ 2·31 = pressure in pounds per sq. inch.

A cu. foot of sea-water = 64·11 pounds (approx.).

1 inch of rainfall on an acre of surface = 22,622 gals.

1 inch of rainfall on an acre of surface = 101 tons (nearly).

PROVISION OF WATER FOR DOMESTIC SUPPLY

(PER PERSON)

Drinking	1 qt.
Food	1 qt.
Washing dishes and cooking vessels	1 gal.
General household purposes	2 gals.
Washing clothes (partial)	3 gals.
Toilet purposes	5 gals.
Bath and W.C.s	13½ gals.
Hotels	30 gals.
Office buildings	15 gals.
Ordinary schools	10 gals.

A horse will require 15 gals. daily; a cow 12 gals.

WATER IN WELLS OR TANKS

(PER FOOT OF DEPTH)

Diameter of well or tank. Feet.	Inches.	Number of gallons.	Diameter of well or tank. Feet.	Inches.	Number of gallons.
1	0	$4\frac{9}{10}$	4	0	78⅜
1	6	11	5	0	122⅜
2	0	19½	6	0	176
2	6	30½	7	0	240
3	0	44	8	0	313

To find cu. contents of wells or circular tanks multiply half circumference by half diameter and multiply result by depth = cu. feet. 1 cu. foot = 6 gals. 1 pt.

COLD-WATER BRANCHES TO VARIOUS POINTS

Supply branches to	Diameter in inches. Low pressure.	High pressure.
Bath	¾–1¼	¾–1
Lavatory	½–¾	½
Water closet flush tank	½–¾	½
Water closet flush valve	1–1¼	¾–1
Kitchen sink	½–¾	½
Pantry sink	½–¾	½
Slop sink	½–¾	½
Urinal	½–¾	½

Low pressure = under 60 feet head = 26 pounds per sq. inch.
High pressure = over 60 feet head.

PRESSURE OF WATER

To ascertain pressure exerted by a still mass of water, multiply vertical height by ·434, which will give pressure per sq. inch of water surface.

WATER HARDNESS

Temporary hardness is due to the presence of carbonate of lime and magnesia, which can be removed by mechanical filtering, chemical means, or boiling (hence furring in boilers, etc.). Permanent hardness is due to the presence of sulphates and nitrates of lime and magnesia.

Hardness is estimated by a scale based on hardness produced by 1 grain of bi-carbonate of lime in 1 gallon of water. Clark's scale assumes distilled (or pure) water at zero. Wanklyn's scale commences at 1.

LOSS OF WATER BY EVAPORATION

Approximate loss of water by evaporation from large reservoirs 27,100 gallons per acre per day.

PRESSURE OF A COLUMN OF WATER

Head of water in feet.	Pressure in pounds per sq. inch.	Pressure in pounds per sq. foot.	Head of water in feet.	Pressure in pounds per sq. inch.	Pressure in pounds per sq. foot.
1	·433	62·40	34	14·728	2,121
2	·866	124·8	35	15·161	2,183
3	1·299	187·04	36	15·594	2,246
4	1·732	249·4	37	16·027	2,308
5	2·165	311·75	38	16·461	2,370
6	2·599	374·25	39	16·894	2,431
7	3·032	436·6	40	17·327	2,495
8	3·465	498·9	41	17·760	2,557
9	3·898	561·3	42	18·193	2,620
10	4·331	623·7	43	18·626	2,632
11	4·764	686	44	19·059	2,745
12	5·198	748·3	45	19·492	2,807
13	5·631	810·8	46	19·925	2,869
14	6·064	873·2	47	20·358	2,932
15	6·497	935·6	48	20·791	2,994
16	6·931	998	49	21·224	3,056
17	7·364	1,060	50	21·657	3,119
18	7·797	1,123	60	25·99	3,742
19	8·230	1,185	70	30·32	4,366
20	8·663	1,248	80	34·65	4,990
21	9·096	1,310	90	38·98	5,613
22	9·530	1,372	100	43·31	6,237
23	9·963	1,435	110	47·64	6,860
24	10·396	1,497	120	51·98	7,482
25	10·829	1,559	130	56·31	8,108
26	11·262	1,622	140	60·64	8,732
27	11·696	1,684	150	64·97	9,356
28	12·129	1,755	160	69·31	9,980
29	12·562	1,809	170	73 64	10,600
30	12·995	1,871	180	77·97	11,230
31	13·428	1,934	190	82·30	11,850
32	13·862	1,996	200	86·63	12,480
33	14·295	2,058			

PUMPS

To find diameter of simple action pump to raise a given volume of water in a given time:

$$d = \sqrt{\frac{\text{ʃ}}{\cdot 034 \times l \times n \times f}},$$

where $\text{ʃ} =$ gallons raised per minute ($\text{ʃ} = d^2 \times \cdot 034 \times l \times n \times f$); $d =$ diameter of barrel in inches; $l =$ length of stroke in feet; $n =$ number of strokes per minute; $f =$ a co-efficient depending upon condition of pump (as a rule taken as $= \cdot 9$).

Power needed to work pump:

$$p = \frac{d^2 \times \cdot 34 \times h \times a}{l},$$

where $d =$ diameter of pump barrel in inches; $h =$ height water has to be raised; $a =$ length of handle between centre of fulcrum and centre of pin in bucket rod; $l =$ length between centre of fulcrum and end of handle where power is applied; $p =$ power applied to end of pump handle.

Length of pump to give required leverage:

$$l = \frac{d^2 \times \cdot 34 \times h \times a}{p}.$$

CO-EFFICIENTS FOR ORIFICES

Discharge from pipes varies according to the sectional area of the jet, or orifice, and a "co-efficient of contraction" is therefore necessary in calculations. Such co-efficients are given below:

Converging tube outlet angle $13\frac{1}{2}°$, measured at narrow end	$c = \cdot 94$
Diverging outlet angle $5°$, measured across narrow end	$c = \cdot 92$
Diverging outlet angle $5°$, measured at wide end	$c = \cdot 55$
Cylindrical tube: when length equals 2 times diameter	$c = \cdot 81$
Cylindrical tube: when length equals 3 times diameter	$c = \cdot 80$
Cylindrical tube: when length equals 4 times diameter	$c = \cdot 78$
Cylindrical tube: when length equals 8 times diameter	$c = \cdot 77$
Cylindrical tube: when length equals 12 times diameter	$c = \cdot 74$
Cylindrical tube: when length equals 24 times diameter	$c = \cdot 72$
Cylindrical tube: when length equals 36 times diameter	$c = \cdot 68$
Short tube projecting inwards	$c = \cdot 60$

ALLOWANCES FOR LOSSES

Orifice in thin plate	$c = \cdot 62$
Loss of head	$c = \frac{22}{29}$
Elbow	$c = 1$
Right-angle bend radius = diameter of pipe	$c = 3$
Right-angle bend radius = 3 diameters	$c = \cdot 14$

HYDRAULIC MEAN DEPTH

To find hydraulic mean depth and area of circular pipes with different depths of floor:

	Hydraulic Mean Depth.	Sectional Area.
Flowing full	$= d \times \cdot 25$	$= d^2 \times \cdot 785$
Flowing $\frac{3}{4}$ full	$= d \times \cdot 296$	$= d^2 \times \cdot 632$
Flowing $\frac{2}{3}$ full	$= d \times \cdot 272$	$= d^2 \times \cdot 556$
Flowing $\frac{1}{2}$ full	$= d \times \cdot 25$	$= d^2 \times \cdot 393$
Flowing $\frac{1}{3}$ full	$= d \times \cdot 186$	$= d^2 \times \cdot 229$
Flowing $\frac{1}{4}$ full	$= d \times \cdot 147$	$= d^2 \times \cdot 154$

d = diameter of pipe in feet.

To find hydraulic mean depth and area of egg-shaped sewers and pipes:

	Hydraulic Mean Depth.	Sectional Area.
Flowing full	$= r \times \cdot 580$	$= r^2 \times 4\cdot 594$
Flowing $\frac{3}{4}$ full	$= r \times \cdot 666$	$= r^2 \times 3\cdot 158$
Flowing $\frac{2}{3}$ full	$= r \times \cdot 633$	$= r^2 \times 3\cdot 023$
Flowing $\frac{1}{2}$ full	$= r \times \cdot 539$	$= r^2 \times 2\cdot 037$
Flowing $\frac{1}{3}$ full	$= r \times \cdot 412$	$= r^2 \times 1\cdot 136$
Flowing $\frac{1}{4}$ full	$= r \times \cdot 338$	$= r^2 \times 0\cdot 745$

r = radius at top; r^2 = radius at bottom.

DISCHARGE FROM PIPES

Cubic feet per minute.

Diameter of pipe. Inches.	Fall		Diameter of pipe. Inches.	Fall	
	1 in 100.	1 in 150.		1 in 100.	1 in 50.
1	·47	·66	4	15·10	21·22
2	2·67	3·77	5	26·39	37·32
$2\frac{1}{2}$	3·60	4·67	6	41·65	58·80
3	7·35	10·39			

VELOCITIES OF DISCHARGE

(EYTELWEIN)

Diameter of pipe.	Fall in feet.	Maximum velocity per minute. Feet.	Maximum discharge per minute.
4	1 in 40	284	146
	1 in 50	254	131
	1 in 60	232	120
6	1 in 60	287	328
	1 in 70	265	303
	1 in 80	249	284
9	1 in 90	284	742
	1 in 100	270	705
	1 in 110	257	670
12	1 in 120	285	1,318
	1 in 150	255	1,177
	1 in 200	221	1,021

Formulæ :

$G = \sqrt{H} \times d^2 \times 16 \times c =$ discharge of gallons per minute where G = gallons; H = head of water in feet; 16 = a constant; c = co-efficient for orifice (*see* table of Co-efficients for Orifices) :

$$f = \sqrt{\frac{(3d)^5 \times h}{l}},$$

where f = gallons of water delivered per minute; d = diameter of pipe in inches; l = length of pipe in yards; h = head of water in feet.

FORMULA FOR WATER OR SEWAGE FLOW

$$V = 55 \sqrt{H \times 2F},$$

where V = velocity in feet per minute; H = hydraulic mean depth in feet; F = fall in feet per mile. For volume of discharge from drain-pipes :

$$D = V \times A,$$

where D = discharge in cu. feet per minute; V = velocity in feet per minute; A = sectional area of flow in super feet.

AMOUNT OF RAIN-WATER OBTAINABLE FROM A GIVEN AREA

Formula :

$$V = \frac{A \times a}{100},$$

where V = volume of supply in gallons per day; A = area of roof (or other area) in sq. feet; a = amount of yearly rainfall for the district in feet. Result given in gallons per annum.

Reservoirs should be large enough for six weeks' supply in a dry locality and for eight weeks' in a wet one to avoid possible waste.

CONTENTS OF TANKS

To find the capacity of a square tank in gallons, multiply length by width, and the product by height in feet, and by $6\frac{1}{4}$ (6·25 being the cubic equivalent of a gallon).

To find the capacity of a circular vessel take the radius (half the diameter), multiply it by itself, and multiply the product by the standard figure 3·141, and the result by the depth.

VIII. LIGHTING, HEATING, AND VENTILATING

MEASUREMENT OF LIGHT

1 lumen = 1 foot-candle power distributed over 1 sq. foot.

Total lumens emitted from a source of light = the mean spherical candle-power multiplied by 4π.

1 foot-candle = illumination of 1 candle-power at 1 foot distance

Candle-power = a standard based on the burning of a spermacetic candle for 1 hour. Actually it is determined by international 10-candle-power standard pentane lamps, or by calibrated electric incandescent lamps.

ILLUMINATION

Illumination = quantity of light falling upon a surface, expressed thus:

$$\frac{\text{candle-power}}{D^2},$$

where D = distance in feet between light source and surface of illumination.

For practical purposes:

$$\text{Surface brightness} = \text{illumination} \times \frac{K}{100},$$

where K = percentage of co-efficient of reflection (*see* table).

CO-EFFICIENT OF REFLECTION

Coloured Surface.	Co-efficient per cent.
Brown distemper (dark)	12
Green distemper	18
Yellow paint (clean)	40
Yellow paint (dulled)	20
Good limewash (clean)	80
Good limewash (dirty)	20-40
Plain deal	45

(*See also* Reflection of Light.)

CONVERSION OF THERMOMETER DEGREES

C. to F., multiply by 9 and divide by 5; then add 32.
C. to R., multiply by 4 and divide by 5
R. to C., multiply by 5 and divide by 4.
R. to F., multiply by 9 and divide by 4; then add 32.
F. to C., first subtract 32, then multiply by 5, and divide by 9.
F. to R., first subtract 32, then multiply by 4, and divide by 9.

Zero Fahrenheit corresponds with minus 17·78 Centigrade and minus 14·22 Réaumur. Zero point Centigrade corresponds with 32° Fahr. On the Fahrenheit scale 32° is the freezing-point and 212° the boiling-point (of distilled water).

REFLECTION OF LIGHT

Colour.	Paint. Per cent.	Paper. Per cent.	Other Material. Per cent.
Polished silvered mirror	—	—	90–95
Pure white glossy surface	90–94	—	—
Silver, burnished	—	—	90–95
Silver, matt	—	—	80–85
White paper, glossy	—	84	–
White paper, matt	—	70–75	
Ivory white or cream	77	—	
Pale primrose or pearl grey	73	—	
Grey white, grey-greenish white, eau-de-nile (pale), primrose, light chrome	70	—	
Caen stone	—	—	68
Pale buff	68	—	—
Gold (varnished) gilding	64	—	65
Eau-de-nile, dark	63	—	—
Aluminium	60	—	60–65
Deep buff, gamboge	60	—	—
Light ochre	56	—	—
Very light grey	55	—	—
Pale azure, blue	52	—	—
Shell pink	51	—	—
Light orange	—	54·8	—
Salmon pink, vieux rose, silver grey	50	—	—
Light grey	—	50	—
Buff stone	—	—	47
Light green	—	46·5	—
Light sage green	43	—	—
Light oak (unstained)	—	—	42
Light yellow	—	40	—
French grey, pale Wedgwood blue	39	—	—
Sage green, apple green	38	—	—
Pale blue on buff stone	—	—	37
Pale blue-green turquoise	36	—	—
Orange, heliotrope	35	—	—
Indian red	30	—	—
Light blue	—	30	—
Sienna, dark buff, tan	28	—	—
Light mauve, emerald green, cobalt blue, vermilion	25	—	—
Dark yellow	—	24	—
Dove grey, olive green	21	—	—
Dark grey	20	—	—
Light red	—	16·2	—
Prussian blue, cardinal red, dark mauve	16	—	—
Dark brown	—	13	—
Crimson	10	—	—
Dark green	—	10	—
Dark blue	—	6·5	—
Crimson, dark brown, purple, deep Prussian blue	5	—	—
Black	4–4·5	4–4·5	—
Black cloth	—	—	4·2
Black velvet	—	—	4

It will be understood from the above that the amount of reflection is increased by a glossy surface ; lessened by a dull, rough one.

Artificial light changes values of colours, and partly of reflection. Where there is an excess of orange-red in the light, pale yellow becomes white ; blue, greenish ; dark blue, black ; reds are brightened.

"Light-diffusing" paint is made up of zinc oxide ground in turpentine,

thinned with turpentine and the addition of white gloss, enamel gloss as a binder and a little blue to absorb the yellow rays in artificial light.

FOOT-CANDLE POWER OF ELECTRIC AND GAS LAMPS

Illumination of 1 foot-candle can be obtained from:
- Electric lighting:
  - Ordinary vacuum lamps, 0·2–0·3 watt per sq. foot.
  - Gas-filled ½-watt lamps, 0·1–0·15 watt per sq. foot.
- Gas lighting:
  - Low-pressure, 1 cu. foot per hour per sq. foot illuminated.
  - High-pressure, 1 cu. foot per hour per 200–300 sq. feet illuminated according to pressure.

These figures are for direct lighting; for semi-indirect lighting increase by 50 per cent.; for indirect lighting by 100 per cent.

UTILISATION EFFICIENCY

$$\frac{\text{Floor area in sq. feet} \times \text{illumination in foot-candles}}{\text{Utilisation efficiency as a decimal} \times \text{burners per lamp}} = \text{Number of lamps required.}$$

The utilisation efficiency factor depends upon the type of lamp adopted in accordance with the work to be done, distance of lamp above working plane, nature of walls, etc.

EFFICIENCY OF LIGHT WELLS

(MEACOCK and LAMBERT, Department of Scientific and Industrial Research)

Formula for determining amount of daylight in a rectangular light well:

$$R = \frac{l}{\pi}\left\{ \tan^{-1}\frac{L}{2D} - \frac{l}{\sqrt{l+\frac{B^2}{D^2}}}\tan^{-1}\frac{L}{2D\sqrt{l+\frac{B^2}{D^2}}} \right\}$$

where L = length of opening; B = breadth of well; D = depth of observation point.

Formula for reflected daylight; the following empirical figures may be used:

$$R = (0{\cdot}4541 \times 10^{-xd})\, p^m,$$

where $x = 0{\cdot}117 + (0{\cdot}149/l)$
p = reflector factor
$m = 1{\cdot}519 + 0{\cdot}33d$
[$l = L/B$ and $d = D/B$]

On actual tests Meacock and Lambert found the actual values slightly lower than those obtained by the combined formulæ.

LOSS OF LIGHT IN GLAZING

$1\frac{1}{4}$-inch polished glass, loss 12 per cent.
$\frac{1}{4}$-inch rolled glass, loss 30 per cent.
26-oz. sheet glass, loss 17 per cent.

The loss depends upon the angle of incidence at which light strikes the glass, also its character. But while rolled glass and etching obstruct light, certain patterned glass may compensate for loss by refraction and diffraction.

ELECTRICAL UNITS

The Ampere is the unit of current.
The Volt is the unit of potential.
The Ohm is the unit of resistance.
The Watt is the unit of power developed in a circuit.
Watts = Volts × Amps.

A micro-ampere is the millionth of an ampere. A microhm the millionth of an ohm ; a megohm is 1,000,000 ohms. A kilowatt is 1,000 watts.

The Board of Trade Unit (B.T.U.) equals $\frac{1{,}000}{746}$, or very nearly $1\frac{1}{4}$ horse-power hours, or 3,402 British Thermal Units (B.Th.U.). The horse-power is ascertained from the wattage by dividing by 746 or by multiplying the kilowattage by 1·34.

- 1 heat unit = 1,048 watt seconds = 772 foot-pounds = 0·252 calories = 0·000388 horse-power.
- 1 watt = 0·00134 horse-power = 3·44 heat units per hour = 0·003 pound of water evaporated per hour.
- 1 kilowatt hour = 1,000 watts = 1·34 horse-power hours = 3·44 heat units = 3 pounds of water evaporated at 212° F.
- 1 horse-power = 746 watts = 2,580 heat units per hour = 2·25 pounds of water evaporated per hour at 212° F.
- 1 pound water evaporated at 212° F. = 0·33 kilowatt hours = 1,148 heat units.

Note.—Electricians often express units of length in mils. 1 mil = ·001 inch.

LIGHTING OF FACTORIES

(Departmental Committee of Home Office)

(*a*) Over the " working area " or that part of floor occupied by bench, machine, etc., 0·25 foot-candle.

(*b*) All other parts of factories and workshops (including passages, stairways, lobbies), 0·1 foot-candle.

(*c*) In all open spaces in which persons are employed during night, 0·05 foot-candle.

These are minima, the measurements being made on a horizontal plane at floor level.

LIGHTING FOR SCHOOLS

Desirable minimum intensity, 8 foot-candles.

The chief difficulty is in daylight illumination, as in quadrangular type of schools the intensity may vary from 80 foot-candles, near the window, to about 4 foot-candles 24 feet from window (A. H. Seymour, *School Buildings*, National Union of Teachers). The Reflection Factor must be taken into consideration (*see* Reflection of Light table, p. 303). "If only 8 per cent. of the light is reflected, the source of light, to give the same results, must be 10 times more powerful than when 80 per cent. is reflected. In badly lighted rooms it is important that the walls should reflect as much light as possible. In well-lighted rooms there is a limit"—beyond which there will be excessive glare from the walls, with discomfort and injury (Seymour).

LIGHTING INTENSITY (ELECTRICITY)

Class of Building.	Watts per sq. foot (averages).	Class of Building.	Watts per sq. foot (averages).
Private house :		Shops (interior)	1·5
Drawing-room	0·6	Shops (windows)	3·5
Dining-room	0·6	Warehouses	0·8
Bedroom	0·35	Billiard table	3·0
Kitchen	0·6	Church	0·5
Hall	0·15	Cinema	0·2
Corridors	0·1	Museum	0·8
Sewing-room	1·25		

AMOUNT OF GAS FOR GENERAL ILLUMINATION

$$\frac{E \times A}{20{,}000} = \text{therms required per hour,}$$

or

$$\frac{E \times A}{40{,}000},$$

where E = degree of illumination in foot-candles required ; A = area of surface to be illuminated in sq. feet ; 20,000 = constant for low-pressure inverted gas ; 40,000 = constant for high-pressure inverted gas.

GAS SUPPLY

$$V = 40\sqrt{\frac{dp}{Sl}}; \quad Q = 780\sqrt{\frac{d^5p}{Sl}}; \quad d = \cdot 073\sqrt{\frac{Q^2S}{p}}$$

where Q = quantity of gas in cu. feet per hour ; l = length of pipe in yards ; d = diameter of pipe in inches ; p = initial pressure in inches ; S = specific gravity of gas (= ·45) ; V = velocity of the gas in feet per second.

HEATING

1 heat unit will raise 55 cu. feet of air in a room having no windows or external walls by 1° F.

Each foot super of external wall will involve a $\frac{3}{10}$ unit to allow the same rise.

Each foot super of glass surface will require a further $\frac{92}{100}$ unit.

To find the number of heat units to warm a room proceed as follows:

Assuming a room 30 × 20 × 12 feet = 7,200 cu. feet, the air to be changed three times per hour and the temperature maintained at 30° F., then:

7,200 × 3 = 21,600 cu feet.

		Heat Units.
21,600 ÷ 55 (*see* note as to 1 unit of heat)		= 393 (approx.)
1 long external wall is 30 × 12 feet	= 360 sq. feet.	
The area of glass in this wall is	= 100 sq. feet.	
	260 sq. feet.	
260 × $\frac{3}{10}$ (*see* note as to external walls)		= 78
100 × $\frac{92}{100}$ (*see* note as to glass)		= 92
Total heat units required to raise temperature of room 1° F.		563

The difference of external temperature and that required in room is 30° F., then:

563 (heat units) × 30 = 16,890.
1 foot super of heating surface (hot water) gives off 175 heat units;
so 16,896 (units) ÷ 175 = 96·5,

which is the superficial area of radiator surface, together with heating pipes required for the room.

MEASUREMENT OF HEAT

Calorie, or Gramme-Calorie = amount of heat required to raise 1 gramme of water 1° C. Kilogram-Calorie, or Engineer's Calorie, = 1,000 above value.

British Thermal Unit of Heat = quantity of heat required to raise the temperature of 1 pound of water 1° F. (taken as from 39·1° F. to 40·1° F.), thus:

	B.Th.U.	Gramme-Calorie.	Foot-pounds.
1 B.Th.U.	= 1	= 252	= 778
1 gramme-calorie	= ·00397	= 1	= 3·09
1 foot-pound	= ·0009645	= ·324	= 1

FORMULA FOR NUMBER OF HEAT UNITS TO RAISE TEMPERATURE OF A SUBSTANCE

$$N = l \times s \times \theta$$

where N = number of heat units ; l = weight of substance in pounds s = specific heat of substance ; θ = range of temperature in ° F.

AIR REQUIRED FOR COMBUSTION

As 1 pound of carbon requires $2\frac{2}{3}$ pounds of oxygen for the complete combustion of carbon to carbonic acid, each pound of carbon $(2\frac{2}{3} \times 4{\cdot}35)$ = 11·6 pounds of air, say 12 pounds ; 1 pound of hydrogen requires 8 pounds of oxygen, or about 35 pounds of air ; 8 pounds of sulphur requires 1 pound of oxygen, or 4·35 pounds of air, therefore :

$$w = 12C + 35\left(H + \frac{O}{S}\right) + 4{\cdot}358 \times 2,$$

where w = weight of air in pounds, C, H, O, S = weights in pounds of carbon, hydrogen, oxygen, and sulphur in pounds.

FLOW OF STEAM IN PIPE

$$W = c\sqrt{\frac{w(p_1 - p_2)d^5}{L}}$$

where W = weight of steam flowing in pounds per minute ; w = density in pounds per cu. foot at entrance to pipe ; p_1 = pressure in pounds per sq. inch at entrance ; and p_2 = pressure at exit ; d = diameter of pipe in inches ; L = length in feet.

When d =	0·5	1	2	3	4	5	6	7	8
Then c =	36·8	45·3	52·7	56·1	57·8	58·4	59·5	60·1	60·7
When d =	9	10	12	14	16	18	20	22	24
Then c =	61·2	61·8	62·1	62·3	62·6	62·7	62·9	63·2	63·3

Loss of pressure in pipe in pounds per sq. inch :

$$p_1 - p_2 = \frac{W^2L}{c^2wd^5}$$

HEATING SURFACE OF SUPERHEATERS IN SQ. FEET

$$\frac{E \times S \times T}{(T^1 - t) \times 5}$$

where E = weight of water evaporated by the boiler in pounds per hour ; S = specific heat of superheated steam (*see* table) ; T = degrees of superheat required ; T^1 = mean temperature of gases before and after passing over superheater ; t = temperature of steam in the boiler, plus half the required superheat.

RATIO BETWEEN RISE IN TEMPERATURE OF WATER AND STEAM AND ATMOSPHERIC PRESSURE

Pressure above atmosphere in pounds per sq. inch.	Temperature. ° F.	Pressure above atmosphere in pounds per sq. inch.	Temperature. ° F.
0	212	55	303
1	215	60	307
2	219	65	312
3	222	70	316
4	224	75	320
5	227	80	324
6	230	85	328
7	232	90	338
8	235	100	344
9	237	110	350
10	239	120	355
11	241	130	361
12	244	140	366
13	246	150	370
14	248	160	375
15	250	170	380
16	252	180	384
18	254	190	388
20	259	200	392
22	262	210	396
24	265	220	399
26	268	240	403
28	271	250	406
32	277	260	409
36	282	270	413
40	286	280	416
45	292	300	422
50	298		

Boiling-point varies with pressure; it is 212° F. at sea-level and decreases by 1° for every 600 feet rise in altitude above sea-level.

GAS PIPES FOR CARCASSING

Discharge per hour. Cu. feet.	Length of pipe. Feet.	Diameter of pipe. Inches.	Discharge per hour. Cu. feet.	Length of pipe. Feet.	Diameter of pipe. Inches.
50	50–150	$\frac{1}{2}$	503	50–600	$1\frac{1}{4}$
100	50–500	$\frac{3}{4}$	400	50–600	$1\frac{1}{4}$
150	50–500	$\frac{3}{4}$	450	50–600	$1\frac{1}{4}$
200	50–600	1	500	50–600	$1\frac{1}{4}$
250	50–600	1	600	—	$1\frac{1}{2}$
300	50–600	1			

Smaller sizes of pipes may be used for branches and brackets.

VALUE OF NON-CONDUCTING MATERIALS

(Prof. R. C. Carpenter)

Description of covering.	Relative amount of heat transmitted.
Plain metal pipe	100·0
2 layers asbestos paper, 1 inch hair felt and canvas cover	15·2
1 inch hair felt	17·0
Hair felt, sectional covering, asbestos lined	18·6
1 thickness asbestos board	59·4
2 layers asbestos paper	77·7
Wool felt, asbestos lined	23·1
Asbestos moulded, mixed with plaster of Paris	31·8
Asbestos felted, pure long fibre	20·1
Asbestos and sponge	18·8
Asbestos and wool felt	20·8

VALUE OF NON-CONDUCTING MATERIALS—*cont.*

Description of covering.	Relative amount heat transmitted
Magnesia moulded, applied as a plaster	22·4
Magnesia, sectional	18·8
Silicate cotton (slag wool), sectional	19·3
Rock wool, fibrous	20·3
Rock wool, felted	20·9
Fossil meal, ¾ inch thick	29·7
Pipe painted with black asphalt	105·5
Pipe painted with light drab lead paint	108·7
Glossy white paint	95·0

HEAT TRANSMISSION CO-EFFICIENTS FOR TYPICAL WALLS

(Building Research Station)

Description of wall section.	Actual thickness. Inches.	Position during test.	Calculated conductivity in gramme-calories per sq. cm. per second for 1 cm. thickness for 1° C. difference of temp.	Calculated conductivity in B.Th.U. per sq. foot per hour for 1-inch thickness for 1° F. difference of temp.	Heat transmitted in B.Th.U. per sq. foot per 24 hours for 1° F. difference of temp. between wall faces.
One-brick walls:					
London Stocks in cement mortar	9	—	0·00210	6·1	16·3
Flettons in lime mortar	8½	—	0·00172	5·0	14·1
Sand-lime bricks in cement mortar	9	—	0·00320	9·3	24·8
Half-brick walls:					
Flettons in cement mortar	4	—	0·00153	4·4	26·5
Flettons in cement mortar with one face ½-inch cement rendered	4½	—	—	—	26·5
Cavity walls [1]:					
Sand-lime bricks on edge: two thicknesses, with headers spanning cavity	9	Horizontal (hot face beneath vertical)	—	—	17·0 19·1
Sand-lime bricks: 11-inch hollow wall with two thicknesses, tied with galvanised-iron ties	11	Horizontal (hot face beneath) vertical	—	—	15·9 17·3
Wall of National Brick Co.'s 12 × 9 × 6-inch hollow terra-cotta bricks	6	Horizontal (hot face beneath vertical)	—	—	19·2 19·7
Same wall as above, ½-inch lime-plastered on one face	6½	Horizontal (hot face beneath)	—	—	19·7 19·3 [2]
"Waller" wall: 1-inch outer slab of gravel concrete, reinforced; inner slab of 3-inch breeze concrete; cavity between	6	Horizontal (hot face beneath)	—	—	24·1
Timber frame construction: ¾-inch weather-boarding, 1-inch rough boarding; 4 × 2-inch studding and lath and plaster	6 approx.	Vertical	—	—	9·6
Composite walls:					
3-inch outer slab of gravel concrete and 3-inch inner slab of breeze concrete with bitumen sheeting between	6 approx.	—	—	—	32·0
Two thicknesses of 2½-inch breeze concrete blocks with 2-inch cavity filled with gravel concrete (1 : 6)	7	—	—	—	20·2
Pisé walls (rammed-in shuttering), clinkers and lime to ½ cu. yard of clinkers	9 approx.	—	0·00280	8·1	21·4
Peterborough clay 2 parts, gravel 1 part	9 approx.	—	0·00300	8·7	22·7

[1] Owing to influence of convection currents in the interspace, the heat transmission values depend upon the position, whether vertical or horizontal.

[2] Increase of conductivity after plastering was probably due to added moisture.

THERMAL CONDUCTIVITY OF CONCRETES AND PLASTERS

(Building Research Station)

Type of material.	Conductivity in B.Th.U. per sq. foot per hour for 1-inch thickness and for 1° F. difference of temperature.
Sand 4, cement 1	3·7
Sand 2, lime 1	3·3
Sand 2, "Sirapite" 1	4·5
"Sirapite"	3·1
Roman mortar (ground brick and lime)	2·9
Granite (to pass ½-inch sieve) 4, cement 1	5·1
Coke breeze (to pass ½-inch sieve) 4, cement 1	4·1
York stone (to pass ½-inch sieve) 4, sand 2, cement 1	7·0
Portland stone (to pass ½-inch sieve) 4, sand 2, cement 1	5·5
Chalk 20, cement 1	2·2
Diatomaceous bricks	0·645–0·958

A damp wall has a higher conductivity than a dry one.

FORMULA FOR HEAT TRANSMISSION THROUGH WALLS

(Building Research Station)

The actual heat transmitted in British thermal units in still air will be given by the formula :

$$H = K(t_1 - t_2)A,$$

where H = British thermal unit ; t_1 = higher temperature in ° F. ; t_2 = lower temperature in ° F. ; A = area of wall in sq. feet ; K = a constant, depending upon construction and material of the wall and condition of the surface.

TABLE OF CONSTANTS

Type of wall.	Value of K.
9-inch plain unplastered brick wall (London Stock)	0·43
4½-inch plain brick wall, unplastered	0·37
4½-inch double-brick wall, 3-inch cavity (without ventilation)	0·33
4½-inch double-brick wall, 3-inch cavity (ventilated top and bottom)	0·42
4½-inch rough ballast concrete (6 : 1)	0·61
4½-inch rough breeze concrete	0·55
6-inch rough ballast concrete	0·57
9-inch concrete blocks with cavity in arch block	0·52
4-inch thick hollow tile	0·44
4-inch ballast concrete wall, outside 2-inch cavity, and 4-inch coke breeze concrete outside (no ventilation)	0·30
4-inch ballast concrete wall, outside 2-inch cavity, and 4-inch coke breeze concrete inside (ventilated top and bottom)	0·35

VELOCITY OF GAS IN CHIMNEYS

(Hutton)

$$V = \frac{8\sqrt{H}\,(T - t)}{3{\cdot}3T},$$

where V = mean velocity of the gases in the chimney in feet per second ; T = temperature in ° F. of the hot gases inside the chimney , t = temperature in ° F. of the air outside the chimney ; H = height of the chimney in feet.

DRAUGHT POWER OF CHIMNEYS

(Temperature of air 62° F. and 600° F. internally)

Height of chimney above fire-grate in feet.	Draught power in inches of water.	Height of chimney above fire-grate in feet.	Draught power in inches of water.
10	0·074	160	1·187
20	0·148	170	1·261
30	0·222	180	1·335
40	0·296	190	1·409
50	0·372	200	1·483
60	0·444	220	1·631
70	0·518	240	1·779
80	0·592	260	1·927
90	0·668	280	2·075
100	0·743	300	2·223
110	0·817	325	2·408
120	0·891	350	2·593
130	0·955	375	2·778
140	1·039	400	2·963
150	1·113		

Minimum height for chimneys in chemical works = 250 feet

AREA OF CHIMNEYS

$$E = \frac{0{\cdot}07wG}{\sqrt{H}},$$

where w = weight of fuel consumed per sq. foot of fire-grate in pounds per hour; G = area of grate in sq. feet; H = height of chimney in feet; E = effective area of chimney required in sq. feet.

If allowance has to be made for retardation due to friction of walls, etc., assuming the layer of air to be 2 inches in thickness, then

$$E = A - 0{\cdot}6\sqrt{A}$$

where A = actual area of chimney at smallest part in sq. feet.

Let S = side of chimney in inches at the smallest part of a square chimney; d = diameter of round chimney at the smallest part in inches, then

$$S = 12\sqrt{E} + A\text{ ; and } D = 13{\cdot}5\sqrt{E} + 4.$$

VITIATION OF AIR

Pure air contains per 1,000 parts: oxygen 208·1, nitrogen 791·5 carbonic acid ·4, with traces of water vapour, ammonia, organic matter salts. In rooms the chief source of vitiation is carbonic acid (CO_2). An adult male expels ·7 cu. foot of carbonic acid per hour; an adult female, ·6; children, ·35 to ·5; candles, ·3; oil-lamps, nearly 1·2; ordinary gas burners (fish tail), 1·2. In practice it is considered allowable that the

content of carbonic acid should be increased to ·6 In order to keep the air at this degree of purity the following formula may be used :

$$Q = \frac{10{,}000a}{b},$$

where Q = fresh air per hour in cu. feet ; a = carbon acid, evolved per hour, in cu. feet ; b = difference in number of parts of carbonic acid per 10,000 parts in the vitiated and the fresh air.

VENTILATION STANDARDS

Description of room.	Cu. feet of air for each occupant per minute. Minimum.	Air interchange per hour with a variable number of occupants
Hospitals :		
Tuberculosis	100	—
Epidemic	80	—
Ordinary	40	—
Workshops and factories :		
Unhealthy trades	40	—
Ordinary	30	—
Cinemas with continuous performances	25	—
Public buildings : churches, halls, theatres, meeting-rooms, not occupied for more than 3 hours continuously	20	—
Schools : classrooms per pupil	30	—
Schools : assembly halls	—	1–3
Small rooms occupied intermittently by not more than 4 persons	—	1–3
Hotel lounges, restaurants, smoking-rooms, etc.	—	6–10
Kitchens, lavatories, etc.	—	6–8
Extreme minimum	13·6	—

FORMULA FOR VELOCITY OF AIR

$$V = c\sqrt{2gC \cdot HT},$$

where V = velocity in feet per second ; c = co-efficient of friction (·5 to ·75) ; g = gravitation unit (32·2) ; C = co-efficient of expansion (·002) ; H = height in feet from inlet to outlet ; T = difference in temperature in ° F. between air intake and outer air.

This formula may be simplified as follows :

$$V = \cdot 5\sqrt{\cdot 129HT},$$

where ·129 is a standard co-efficient.

FORMULA FOR QUANTITY OF AIR

$$Q = AV,$$

where Q = quantity of air in feet per second ; A = sectional area of inlet or outlet in sq. feet ; V = velocity of air in feet per second.

Desirable velocity (change of air) in schools = 25 feet per minute. In actual practice this may vary, with open windows, from 24 to 500 feet per minute at 3 feet from floor and 25–220 feet 6 feet from floor, unless regulated.

AIR VELOCITIES

Velocity in feet per second.	Equivalent velocity in miles per hour, approx.	Sensation
3	2	Just perceptible
6	4	Gentle
18	12	Gently brisk
36	25	Very brisk
50	35	High wind
66	45	Very high wind
88	60	Strong gale
105	70	Violent gale
117	80	Hurricane
146	100	Violent hurricane

FLOW OF AIR IN FLUES

Discharge in cu. feet per minute through flue 1 sq. foot in section, with allowance of 50 per cent. for friction, etc.

Difference in inside and outside temperature in ° F.	Total height of air column in feet (from level in inlet to top of outlet).					
	1	2	5	10	20	30
5	23	33	51	72	102	125
10	32	46	72	102	145	177
15	40	56	89	125	177	223
20	46	65	102	205	205	250
30	57	80	127	247	247	310
40	65	92	146	291	291	357

ATMOSPHERIC PRESSURE

The pressure of $\frac{1}{2}°$ is 7·348 pounds to the sq. inch.
The pressure of 1° is 14·696 pounds to the sq. inch.
The pressure of $1\frac{1}{2}°$ is 22·014 pounds to the sq. inch.
The pressure of 2° is 29·392 pounds to the sq. inch.
The pressure of $2\frac{1}{2}°$ is 36·740 pounds to the sq. inch.
The pressure of 3° is 44·088 pounds to the sq. inch.
The pressure of $3\frac{1}{2}°$ is 51·436 pounds to the sq. inch.
The pressure of 4° is 58·784 pounds to the sq. inch.
The pressure of $4\frac{1}{2}°$ is 66·132 pounds to the sq. inch.
The pressure of 5° is 73·480 pounds to the sq. inch.

POROSITY OF BUILDING MATERIALS

(Building Research Station)

The amount of air passing through a wall can be calculated from the formula :

$$V = \frac{Ap\theta}{t},$$

where V = volume of air in cu. feet passing per hour ; A = area of the material in sq. feet ; p = difference of pressure on the two sides of wall in pounds per sq. foot ; θ = porosity ; t = thickness of wall in feet.

TABLE OF POROSITY

	Air.
Concrete slab of ¾ washed ballast, sand, and cement 4 × 2½ × 1 inch	·0011–·0014
Coke breeze and cement (6 : 1) ; one side rendered in cement and sand (1 : 3), ¾-inch thick	·0033–·0073
Concrete slab of ¾ washed ballast, sand, and cement (4 × 2½ × 1 inch), ordinary mixing	·0011–·0010
Stock brick in cement and sand (1 : 3)	·13–·22
Fletton brick in cement and sand	·05–·17
Plaster : cement and sand (average for surface)	0·022
Plaster : Sirapite (average for surface)	0·022
Plaster : lime plaster, rough	10·7
Plaster : lime plaster, smooth	3·4
Plaster : lime plaster and cement, rough (average 7·2)	15·7
Plaster : lime plaster and cement, smooth (average 11·2)	7·0
Plastered slab with unvarnished paper	6·2
Plastered slab with varnished paper	4·3

IX. MISCELLANEOUS

SLIDE RULES

Slide rules are small instruments designed to multiply and divide logarithms, and also make calculations in evolution and involution of

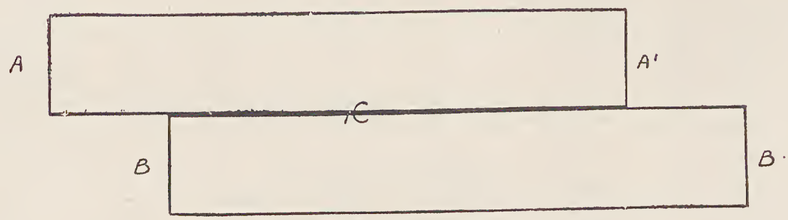

Fig. 151.—Sliding rule.

numbers, mechanically, thus doing away with the need for lengthy calculations or the use of tables. The principle of the mechanism is this: there are a bottom, stationary, and a top, sliding, rule, both marked with scales. On referring to the diagram it will be seen that if the line BC is added to AB, the result will be AC. If AA^1, the slide, and BB^1 are both marked uniformly with a scale, or scales, from A to A^1, and B to B^1, AB will represent numbers at B on the upper scale and BC the number at C on the lower scale, so that the result of the addition AB + BC is the number found at C on the upper scale. Thus, if AA^1 and BB^1 are graduated with the numbers 1 to 100 at the distance corresponding to logarithms, then an addition of the lengths AB and BC the logarithms are added and AC gives the logarithm product, because, owing to the method of graduation this product is read off at C on the upper scale. But for division the divisor on the lower scale must be brought immediately below the dividend on the upper scale, and the answer is read on the upper scale, above 1 on the lower scale, the result being obtained by subtracting the logarithms. The common 10-inch slide rule, which gives results correct to about 1 in 500, consists of two pairs of scales, with a cursor and hair line for accurate reading. The top and bottom scales give for any position of the hair line the corresponding numbers and

their squares, or conversely numbers and their square roots. On the slide, upper rule, the back is marked with three scales, giving sines, tangents, and logarithms.

Variations of the slide rule are the watch-shaped calculators, and the cylindrical slide scale, 12 inches long by 3 inches in diameter, equal to a rule 83 feet long.

SEATING CAPACITY

Public Halls or Theatre: Space per person (liberal) 2 feet 6 inches × 3 feet = $7\frac{1}{2}$ sq. feet; (ordinary) 2 feet 2 inches × 2 feet 9 inches = $5\frac{1}{2}$ sq. feet. A usual over-all allowance, including lobbies, is $7\frac{1}{2}$ sq. feet per person.

Restaurants: Lyons & Co.'s Corner House, Piccadilly Circus, on the first floor has an area of 8,550 sq. feet, which gives ample accommodation for 760 seats, divided up into 150 tables for 4 persons, 10 tables for 6, and 15 for 2.

Temporary Dining-rooms and Refectories: Width, not less than 12 feet (allowing 1 foot 6 inches per person on each side of table 3 inches wide), and 3 feet free space on each side. Space for each person at table, not less than 2 feet 6 inches (2 feet for children). Liberal allowance 18 feet across room and 2 feet 9 inches for each person at table. Allow not less than 4 feet free at top and bottom of tables (if serving tables or sideboards, allow extra for these). Tables placed in rows, allow not less than 4 feet 6 inches between each.

DIMENSIONS FOR CHURCHES

Accommodation, including whole of main building per person	5–7 feet super
Size of pews (English Church Commissioners' rule)	20 × 34 inches
Size of pews for free sittings	20 × 27 inches
Size of pews for children	14 × 17 inches
Height of seat from floor	18 inches
Width of seat	13–15 inches
Book board, height from floor	32 inches
Book board, width	$4\frac{1}{2}$ inches

DIMENSIONS FOR SCHOOLS

Width	16–20 feet
Height, if ceiled at wall plate	12 feet
Height, if floor space exceeds 300 feet super	13 feet
Height, if floor space exceeds 600 feet super	14 feet
Height to wall plate, if ceiled to rafters and cellar beam	11 feet
Height from floor to cellar beam	14 feet
Height of window sills above floor	12 feet
Length of desk per child juniors	18 inches
Length of desk per child, seniors	22 inches
Minimum distance of seats from back to back	29 inches

The mean floor space per person may be taken as 15 sq. feet. At St. Paul's School, West Kensington, London, it is $17\frac{1}{2}$ sq. feet; at the City of London Schools, it is $13\frac{1}{2}$ sq. feet. In the St. George's Buildings, Heritage Craft Schools, Chailey, Sussex, the main dormitories measure 65 × 20 feet and accommodate 22 beds (1932).

COVERING POWERS OF PAINTS, ETC.

(After A. S. Jennings)

Material	Sq. yards per gallon
Oil varnish	85–100
Enamel—flat or glossy	70–80
Flat oil paints and flat oil finishes :	
First coat on wood or plaster	50–55
Second coat on wood or plaster	60–65
Finishing coat on wood or plaster	75–80
Under coats	75–90
Paste water paints—7-lb. thin and applied to bare plaster	30–35
Stains (solignum type)	50–60
Shellac varnish	45–55

Whitewash or ceiling distemper, 550 sq. yards per cwt.

COVERING CAPACITY OF WHITE-LEAD PAINT

	White lead.		Paste driers.		Linseed oil		Turpentine.
	Lb.	oz.	Lb.	oz.	Galls.	Pints.	Pints.
On wood or plaster :							
First coat	25	0	2	0	2	0	1½
Second coat	16	10	1	11		4	4
Third coat	16	10	2	6		8	8
On iron :							
First coat	16	10	1	1		5	2½
Second coat	16	10	1	1		8	8
Third coat	16	10	1	15		10	4

WALL-PAPERS

One piece English wall-paper = 12 yards × 21 inches = 63 sq. feet.
One piece French wall-paper = 9 yards × 18 inches = 40½ sq. feet.
One piece American wall-paper = 8 yards × 18 inches = 36 sq. feet.

NUMBER OF PIECES OF ENGLISH PAPER REQUIRED

Feet super of walls.	Height of room from skirting to cornice, in feet									
	6	7	8	9	10	11	12	13	14	15
	Number of pieces.									
32	4	4	5	5	6	6	7	7	8	8
36	4	5	5	6	6	7	7	8	9	9
40	4	5	6	6	7	8	8	9	9	10
44	5	5	6	7	8	8	9	10	10	11
48	5	6	7	7	8	9	10	10	11	12
52	6	6	7	8	9	10	10	11	12	13
56	6	7	8	8	9	10	11	12	13	14
60	6	7	8	9	10	11	12	13	14	15
64	7	8	9	10	11	12	13	14	15	16
68	7	8	9	10	11	12	13	15	16	17
72	7	9	10	11	12	13	14	15	17	18
76	8	9	10	11	13	14	15	16	17	19
80	8	9	11	11	13	15	16	17	18	20
84	9	10	11	12	14	15	17	18	19	21
88	9	10	12	12	14	16	17	19	20	21
92	9	11	12	13	15	17	18	19	21	22
96	10	11	13	13	16	17	19	20	22	23
100	10	12	13	15	16	18	20	21	24	24

The above applies only to plain papers, or those with small repeat patterns, a slight allowance being made for waste. Expensive papers with large or elaborate patterns entail greater waste, as more allowance must be made for matching patterns.

CEILING PAPERS

Measurement in feet round the room.	No. of pieces.	Measurement in feet round the room.	No. of pieces.
20–28	1	74–78	7
30–40	2	80–82	8
42–48	3	86–88	9
52–58	4	90–92	10
60–66	5	96–98	11
68–70	6	100	12

FIRE RESISTANCE OF WIRED GLASS

Tests by British Fire Prevention Committee with Pilkington's wired glass. Three openings glazed with wired glass, embedded respectively (1) in brick reveal, divided by a vertical T-iron mullion ; (2) bedded in brick reveal, window divided by a concrete mullion ; (3) glazed in steel frame divided into two lights, the glazing being fixed by angle-iron steps. Exposed to gas flames for 90 minutes, the temperature being raised above 1,500° F., but below 1,650° F. The glass began to crack 2 or 3 minutes after lighting of gas, and continued to do so, but when gas was extinguished fire had not passed through the glazing. Water was applied, 2 minutes after extinguishing gas, on the fire side, through a 5-inch nozzle on a pressure of about 60 pounds ; the glass sintered all over, but only in one case (No. 3) did it pass through the glass. A later test, with " Georgian " rectangular-mesh electrically-welded steel-wire armoured glass, five " windows " passed the fire test, no fire passing through the cracked glass, and water only trickled through two out of the five " windows."

PLATE GLASS

Thickness. Inches.	Sizes. Inches.	Weights per foot square (approx.). Lb.	Uses.
$\frac{1}{8}$	90 × 40	2	$\frac{1}{8}$–$\frac{3}{16}$-inch for general glazing.
$\frac{3}{16}$	110 × 72	$2\frac{3}{4}$	$\frac{1}{4}$-inch for better-class glazing,
$\frac{1}{4}$	165 × 110	$3\frac{1}{2}$	public offices, shop fronts, frame-
$\frac{5}{16}$	180 × 130	$4\frac{1}{2}$	less lights, table tops, shelves.
$\frac{3}{8}$	280 × 130	$5\frac{1}{4}$	$\frac{3}{8}$-inch for large shop fronts,
$\frac{1}{2}$	180 × 120	7	shelves in hospitals, cafés, etc.
$\frac{5}{8}$	132 × 114	$8\frac{3}{4}$	$\frac{1}{2}$-inch ship saloon windows,
$\frac{3}{4}$	124 × 108	$10\frac{1}{2}$	hospital operating tables.
$\frac{7}{8}$	120 × 100	$12\frac{1}{4}$	$\frac{1}{2}$–$1\frac{1}{2}$-inch floors, decks, aquarium
1	110 × 96	14	tanks.
$1\frac{1}{4}$	108 × 72	$17\frac{1}{2}$	

Rolled plate in sheets $\frac{1}{8}$ inch, $\frac{3}{16}$ inch, $\frac{5}{16}$ inch, $\frac{3}{8}$ inch, $\frac{1}{4}$ inch thick.

" Rough cast " rolled sheets for pavement floors and cellar lights from $\frac{3}{8}$ inch, $\frac{1}{2}$ inch, $\frac{5}{8}$ inch to $1\frac{3}{4}$ inches thick.

Sheet Glass

	Size of sheets.
15 oz., average thickness $\frac{1}{13}$ inch . . .	60 × 40 inches
21 oz., average thickness $\frac{1}{10}$ inch . . .	81 × 42 inches or 68 × 50 inches
26 oz., average thickness $\frac{1}{8}$ inch . . .	81 × 45 inches or 70 × 51 inches

32-oz., 36-oz., and 42-oz. sheet glass is also made.

Fluted Sheet Glass

15 oz.	55 × 36 inches or 50 × 40 inches
21 oz.	65 × 40 inches or 55 × 50 inches
26 oz.	60 × 40 inches or 50 × 50 inches

APPENDIX

BRITISH STANDARDS INSTITUTION

INCORPORATED BY ROYAL CHARTER

SECTIONAL LIST OF BRITISH STANDARDS

(These Standards are obtainable from the British Standards Institution, 2 Park Street, London, W.1.)

BUILDING

" Add." signifies that an Amendment is issued with this Standard.

† *War Emergency Standards.*

‡ *In the case of publications marked " out of print," a limited number of copies are held available for loan purposes and a copy may be borrowed if desired.*

§ *A summary of this Standard is included in Handbook No. 3.*

GENERAL

Handbook No. 3, 1953. British Standards for Building Materials and Components for Housing includes the essential features of 268 British Standards. 30/–
The Standards, summaries of which are included in the Handbook are indicated in this list by §.

Handbook No. 5, 1948. Domestic fuel and power-using appliances. 12/6.

This handbook, which is divided into four parts, combines all the published British Standards for domestic appliances, in abridged form.

Handbook No. 9, 1949. Domestic electrical installations. 12/6.

This handbook contains a summary of 36 British Standards relating to domestic electrical installations.

Handbook No. 12, 1950. British Standards for Water Fittings. 25/–.

This Handbook contains reference to twenty-six standards for water fittings referred to in the Ministry of Health Model Byelaws, Series XXI. It also includes extracts from a number of related standards. The Model Byelaws are reproduced by permission of the Controller of H.M. Stationery Office.

B.S.

§476 : 1953 Fire tests on building materials and structures. 4/–.

560 : 1934 Engineering symbols and abbreviations. 5/–. *Add.* Sept., 1945.

§648 : 1949 Schedule of weights of building materials. 5/–.

661 : 1936 Glossary of acoustical terms and definitions. 4/–. *Add.* Oct., 1952.

§685 : 1951 Sequence of trade headings and specification items for building work. 2/6.

874 : 1939 Definitions of Heat Insulating Terms. 2/6.

1151 : 1949 Form of time and wages sheet and pay packet for the building and civil engineering contracting industries. 3/–.

1151 : Part 2 : 1945 Guaranteed minimum reckoners for the building and civil engineering contracting industries. 1/–. *Add.* Nov., 1951.

§1192 : 1953 Drawing office practice for architects and builders. 7/6.

1265–68 : 1945 Drawing boards and tee squares. 2/6.

B.S.

1311 : 1946 Sizes and contents arrangement for manufacturers' trade and technical literature (building industry). 1/–.

1340/43 : 1946 Drawing papers (tracing detail and cartridge). 2/–.

1347 : 1947 Architects', engineers' and surveyors' boxwood scales. 2/–. *Add.* October, 1951.

1347 : Part 2 : 1951 Boxwood scales. Part 2 : Scales for quantity surveyors. 2/–.

1635 : 1950 Graphical symbols for fire protection drawings. 3/–.

1677 : 1950 Draughtsmen's drawing pins. 1/–.

1708 : 1951 Modular co-ordination. First report of the British Standards Institution Committee. 2/6.

1709 : 1951 Nomenclature of drawing instruments. 2/–.

§1710 : 1951 Colour identification of pipe lines. 2/6.

§1982 : 1953 Fungal resistance of manufactured building materials. 2/–.

MATERIALS

ADHESIVES

§745 : 1949 Animal glue for wood. 2/–. *Add.* September, 1950.

§1203 : 1945 and §1204 : 1945 Synthetic resin adhesives for plywood. *Add.* June, 1952. Cold setting synthetic resin adhesives, (1 volume.) 4/–. *Add.* September, 1950 and February, 1953.

§1310 : 1950 Coal tar pitches for building purposes. 3/–.

§1444 : 1948 Cold-setting casein glue for wood. 2/–. *Add.* September, 1950.

AGGREGATES

812 : 1951 Sampling and testing of mineral aggregates, sands and fillers. 6/–. *Add.* May, 1952 and Feb., 1953.

§877 : 1939 Foamed blastfurnace slag for concrete aggregate. 2/6. *Add.* April, 1947.

§882, 1198, 1199, 1200, 1201 : 1944 (one volume). Concrete aggregates and building sands from natural sources. 7/6. *Add.* May, 1947.

B.S.

§1047 : 1952 Air-cooled blastfurnace slag coarse aggregate for concrete. 4/–.

§1165 : 1947 Clinker aggregate for plain concrete. 2/6.

ALUMINIUM

§1161 : 1951 Aluminium and Aluminium Alloy Sections. 5/–. *Add.* Jan., 1952.

BRICKS

§187 : 1942 Sand lime (calcium-silicate) bricks. 2/6. *Add.* Dec., 1947.

§657 : 1950 Dimension of common building bricks. 1/–.

§1180 : 1944 Concrete bricks and fixing bricks. 2/6. *Add.* May, 1948.

§1257 : 1945 Methods of testing clay building bricks. 2/6.

§1301 : 1946 Clay engineering bricks. 2/–.

BUILDING BOARD

§1142 : 1953 Fibre building boards. 4/–. *Add.* April and July, 1953.

§1230 : 1945 Plaster board. 2/–. *Add.* April, 1952.

BUILDING PAPER

§1521 : 1949 Waterproof building papers. 2/6. *Add.* Sept., 1949.

CEMENT, CONCRETE, LIME AND PLASTERS

§12 : 1947 Portland cement (ordinary and rapid-hardening). 3/6. *Add.* May, 1948, Jan., 1950, Aug., 1950, Jan., 1952, Feb., 1952, Aug., 1952.

§146 : 1947 Portland blastfurnace cement. 5/–. *Add.* May, 1948, Jan., 1950, Aug., 1950, May, 1952, Aug., 1952.

§890 : 1940 Building limes. 5/–.

§915 : 1947 High alumina cement. 4/–. *Add.* Jan., 1950, Aug., 1950, Aug., 1952.

§1014 : 1942 Pigments for colouring cement, magnesium oxychloride and concrete. 2/6.

§1191 : 1944 Gypsum and anhydrite building plasters. 4/–. *Add.* Sept., 1945 and Jan., 1953.

1370 : 1947 Low heat Portland cement. 3/6. *Add.* Dec., 1948, Jan., 1950, Aug., 1950, Aug., 1952.

B.S.

§1878 : 1952 Corrugated copper jointing strip for expansion joints. 2/–.

§1881 : 1952 Methods of testing concrete. 10/–.

§1926 : 1953 Methods of specifying ready mixed concrete. 2/6.

PD 572 : 1947 Specification for a typical vibration machine for compacting mortar cubes for testing cement. Specification and four drawings. £1.

GLASS

§952 : 1953 Glass for glazing: Classification and terminology. 5/–.

PLYWOOD

§588 : 1935 Grading of plywood (veneered with oak, mahogany, walnut, teak and other ornamental woods). Temporarily out of print. ‡

§1455 : 1948 British-made plywood for building and general purposes. 5/–.

STEEL

§4 : 1932 Channels and beams for structural purposes, dimensions and properties of. *Add.* April, 1934. (Partly superseding B.S. 6 : 1924.) 2/6.

§4a : 1934 Equal angles, unequal angles and tee bars for structural purposes, dimensions and properties of. (Partly superseding B.S. 6 : 1924.) 2/6.

6 : 1924 (Extract from) Bulb angles, and bulb plates for structural purposes, dimensions and properties of. (See B.S. 4 and 4a.) 2/6.
(N.B.—Approximate formulæ for all sections are included in the extract from B.S. 6 : 1924.)

§15 : 1948 Structural steel. 3/–.

§405 : 1945 Expanded metal (steel) for general purposes. 2/6.

§449 : 1948 The use of structural steel in building. 7/6. *Add.* July, 1949.

§548 : 1934 High tensile, structural for bridges, etc., and general building construction. 2/6. *Add.* May, 1936, Feb., 1938 and June, 1942.

B.S.

§785 : 1938 Rolled steel bars and hard drawn steel wire for concrete reinforcement. 2/6. *Add.* June, 1942, Jan., 1952.

†§968 : 1941 High tensile (fusion welding quality) structural steel for bridges, etc., and general building construction. 3/–. *Add.* Aug., 1943.

§1144 : 1943 Cold twisted steel bars for concrete reinforcement. 2/6.

§1221 : 1945 Steel fabric for concrete reinforcement. 3/–. *Add.* July, 1948.

1478 : 1948 Bending dimensions of bars for concrete reinforcement. 2/–.

TIMBER

373 : 1938 Testing small clear specimens of timber, methods of. 2/–.

§565 : 1949 Glossary of terms applicable to timber, plywood and joinery. 5/–.

§881 and 589 : 1946 Nomenclature of commercial timbers (including botanical names and sources of supply). 7/6.
Including:

§PD 841 : 1948 Provisional supplement to B.S. 881 and 589 : 1946, Nomenclature of commercial-timbers. (Available separately if required, price 2/–).

§1186 : Part 1 : 1952 Quality of timber in joinery. 4/–.

§1579 : 1953 Connectors for timber. 3/6.

1811 : 1952 Methods of test for wood chip boards, wood waste boards and similar boards. 2/–.

§1860 : 1952 Structural softwood. Measurement of characteristics affecting strength. 2/6. *Add.* July, 1952.

STRUCTURAL COMPONENTS

DAMP-PROOF COURSES

§743 : 1951 Materials for damp-proof courses. 2/6.

†1067 : 1942 Coal tar pitch felt damp-proof courses. 1/6.

§1097 : 1943 Mastic asphalt for damp-proof courses and tanking. 2/6. *Add.* Nov., 1952.

§1418 : 1947 Mastic asphalt damp-proof courses and tanking. 2/6. *Add.* May, 1948.

B.S. **DOORS**

§459 : Part 1 : 1944 Panelled and glazed wood doors. 2/6. *Add.* March, 1945, Oct., 1948, Nov., 1951 and Dec., 1952.

§459 : Part 2 : 1945 Flush wood doors. 2/6. *Add.* Oct., 1948, July, 1949, Feb., 1950.

§459 : Part 3 : 1951 Plywood faced fire-check flush doors and wood and metal frames (half-hour and one-hour types). 2/6.

§459 : Part 4 : 1951 Matchboarded doors. 2/–.

§644 : Part 1 : 1951 Wood casement windows. 3/–. *Add.* July, 1951, Sept., 1951, Feb., 1952, Aug., 1952.

973 : 1945 Code of practice for glazing and fixing of glass in buildings. 2/–.

§990 : 1945 Metal casement windows and casement doors for domestic buildings. 6/–. *Add.* Dec., 1945, Jan., 1949, Sept., 1949, May, 1951 and Nov. 1952.

§1245 : 1951 Metal door frames (steel). 2/6.

§1567 : 1953 Wood door frames and linings. 4/–. *Add.* July, 1953.

FLOORING

§776 : 1938 Materials for use in the manufacture of magnesium oxychloride flooring composition. 4/–.

§810 : 1950 Sheet linoleum and cork carpet. 2/–. *Add.* Feb., 1951.

§1076 : 1942 Mastic asphalt for flooring. 2/6.

†§1177 : 1944 Pitch mastic flooring, incorporating lake asphalt. 2/–.

§1187 : 1944 Wood blocks for floors. 2/–.

§1190 : 1944 Hollow clay building blocks. 2/–. *Add.* Sept., 1952.

§1197 : 1944 Concrete flooring tiles and fittings, dimensions and workmanship. 2/–.

§1246 : 1945 Metal skirtings, picture rails and angle beads. 2/–.

§1286 : 1945 Clay tiles for flooring. 2/–. *Add.* May, 1946 and October, 1947.

§1297 : 1952 Grading and sizing of softwood flooring. 2/–.

§1324 : 1946 Asphalt tiles for paving and flooring—natural rock asphalt. 2/–. *Add.* Feb., 1952 and Dec., 1952.

B.S.

1325 : 1946 Asphalt tiles for paving and flooring—mineral aggregate with no inherent bitumen. 2/–. *Add.* Feb., 1952, Dec., 1952 and Feb., 1953.

§1375 : 1947 Coloured pitch mastic flooring. 2/6.

§1410 : 1947 Mastic asphalt flooring—natural rock containing 6–10 per cent. bitumen. 2/6.

§1450 : 1948 Black pitch mastic flooring. 2/6. *Add.* Feb., 1951, Aug. 1952 and Dec., 1952.

§1451 : 1948 Coloured mastic asphalt flooring limestone aggregate). 2/6. *Add.* Dec., 1952.

§1711 : 1951 Solid rubber flooring. 2/–.

§1783 : 1951 Coloured pitch mastic flooring incorporating lake asphalt and bitumen. 2/6. *Add.* Dec., 1952.

§1863 : 1952 Felt-backed linoleum. 2/–.

JOINERY

§459 : Part 1 : 1944 Panelled and glazed wood doors. 2/6. *Add.* March, 1945, Oct., 1948, Nov., 1951 and Dec., 1952.

§459 : Part 2 : 1945 Flush wood doors. 2/6. *Add.* Oct., 1948, July, 1949 and February, 1950.

§459 : Part 3 : 1951 Plywood faced fire-check flush doors and wood and metal frames (half-hour and one-hour types). 2/6.

§459 : Part 4 : 1951 Matchboarded doors. 2/–.

§583 : 1934 Wooden gates. 2/–.

§584 : 1946 Wood trim. 2/6.

§585 : 1944 Wood stairs with close strings. 2/–.

§644 : Part 1 : 1951 Wood casement windows. 4/–. *Add.* July, 1951, Sept., 1951, Feb., 1952.

§644 : Part 2 : 1946 Wood windows. Double-hung sashes with cased and solid frames. 2/6. *Add.* July, 1947 and Oct., 1948.

§1186 : Part 1 : 1952 Quality of timber in joinery. 4/–.

§1195 : 1948 Kitchen fitments and equipment. 6/–. *Add.* July, 1952.

§1285 : 1945 Wood surrounds for metal windows. 2/6. *Add.* July, 1948 and March, 1949.

B.S.

§1292 : 1945 Storage fitments for living-rooms and bedrooms. 2/6. *Add.* July, 1952.

§1567 : 1953 Wood door frames and linings. 4/–.

ROOFING

§402 : 1945 Clay plain roofing tiles and fittings. 4/–.

§473 : 1944 Concrete plain roofing tiles and fittings. 4/–.

§550 : 1945 Concrete interlocking roofing tiles. 2/6. *Add.* July, 1952.

§680 : 1944 Roofing slates. 2/6.

690 : 1953 Asbestos-cement slates and sheets. 4/–.

§747 : 1952 Classification of roofing felts, 4/–.

§798 : 1938 Galvanised corrugated steel sheets (primarily for use in the home market). 2/–.

§849 : 1939 Plain sheet zinc roofing, code of practice for. 2/6. *Add.* June, 1939.

§899 : 1952 Rolled copper sheet and strip for general purposes. 2/6.

§988 : 1941 Mastic asphalt for roofing, type A limestone aggregate. 2/6. *Add.* Aug., 1945 and Nov., 1952.

§1162 : 1944 Mastic asphalt for roofing. Natural rock with high bitumen content (6–10 per cent.) 2/6.

§1178 : 1944 Milled lead sheet and strip for building purposes. 2/–.

§1190 : 1951 Hollow clay building blocks. 2/–. *Add.* Sept., 1952.

§1318 : 1946 Wood battens for slating and tiling. 1/–.

§1424 : 1948 Clay single-lap roofing tiles and fittings (dimensions and workmanship only). 5/–. *Add.* Nov., 1948.

§1569 : 1949 Copper sheet and strip for roofing. 1/–.

WALLING

§187 : 1942 Sand lime (calcium-silicate) bricks. 2/6. *Add.* Dec., 1947.

§492 : 728 and 834 : 1944 (one volume). 3/–. *Add.* Dec., 1946.
Precast concrete blocks.
B.S. 492. Solid partition blocks.
B.S. 728. Hollow partition blocks.

B.S.

B.S. 834. Blocks for rendered walls.

§493 : 1945 Airbricks and gratings. 2/–.

§657 : 1950 Dimensions of common building bricks. 1/–.

§882 : 1944 Coarse and fine aggregates from natural sources to concrete. 7/6.
(Including B.S. 1198–1201 : 1944.)

§1105 : 1951 Wood wool building slabs. 2/–.

1146 : 1943 Reinforced brickwork. 2/–.

§1180 : 1944 Concrete bricks and fixing bricks. 2/6. *Add.* May, 1948.

§1190 : 1951 Hollow clay building blocks. 2/–. *Add.* Sept., 1952.

§1198 : 1944 Natural sands and crushed natural stone sands for plastering.

§1199 : 1944 Natural sands and crushed natural stone sands for external renderings.

§1200 : 1944 Natural sands and crushed natural stone sands for brickwork (plain and reinforced) and for masonry.

§1201 : 1944 Aggregates for granolithic concrete floors.
The above four standards are included with B.S. 882 in one volume.

§1207 : 1944 Hollow glass blocks. 2/–. *Add.* Oct., 1946.

§1217 : 1945 Cast stone. 2/6.

§1232 : 1945 Natural stone for building. 2/–.

§1233/35 : 1945 Copings (clayware, cast concrete and natural stone). 3/–.

§1236/40 : 1945 Sills and lintels. Clayware cast concrete and natural stone. 7/6. *Add.* Dec., 1946 and Dec., 1952.

§1243 : 1945 Metal wall ties. 2/6.

§1281 : 1945 Glazed earthenware wall tiles. 2/–.

§1317 : 1946 Wood laths for plastering. 1/–.

§1364 : 1947 Aerated concrete building blocks (dimensions only). 1/–.

§1369 : 1947 Metal lathing (steel) for plastering. 1/–. *Add.* June, 1951.

B.S. **WINDOWS**

§644 : Part 1 : 1951 Wood casement windows. 4/–. *Add.* July, 1951, Sept., 1951, Feb., 1952, Aug., 1952.

§644 : Part 2 : 1946 Wood windows. Double-hung sashes with cased and solid frames. 2/6. *Add.* July, 1947 and Oct., 1948.

§644 : Part 3 : 1951 Wood double-hung sash and case windows (Scottish type). 3/–.

973 : 1945 Code of practice for glazing and fixing of glass in buildings. 2/–.

§990 : 1945 Metal casement windows and casement doors for domestic buildings. 6/–. *Add.* Dec., 1945, Jan., 1949, Sept., 1949, May, 1951 and Nov., 1952.

1209 : 1945 Glass internal sills to wood and metal windows. 2/–.

§1236/40 : 1945 Sills and Lintels. 7/6. *Add.* Dec., 1946 and Dec., 1952.

§1285 : 1945 Wood surrounds for metal windows. 2/6. *Add.* July, 1948 and March, 1949.

§1422 : 1948 Metal window subframes, sills and window boards. 3/–.

§1787 : 1951 Steel windows for industrial buildings. 4/–.

PIPES AND FITTINGS

DRAIN PIPES AND FITTINGS

§65 : 1952 Salt-glazed ware pipes. 3/–

§78 : 1938 Cast-iron pipes (vertically cast) for water, gas and sewage and special castings for use therewith. 12/6, including addendum P.D. 1166 weights of special castings, available separately if required, price 3/–. *Add.* Nov., 1938, Sept., 1943, January, 1948 and March, 1953.

§437 : 1933 Cast iron spigot and socket drain pipes. 2/6. *Add.* Aug., 1943.

§497 : 1952 Cast manhole covers, road gully gratings and frames for drainage purposes. 5/–.

§534 : 1934 Steel spigot and socket pipes and specials for water, gas and sewage. 5/–. *Add.* July, 1952.

B.S.

§539 : Part 1 : 1951 Dimensions of drain fittings. Salt-glazed ware and glass (vitreous) enamelled salt-glazed fireclay. 5/–. *Add.* April, 1952.

§539 : Part 2 : 1951 Dimensions of drain fittings—Scottish type. Salt-glazed ware and glass (vitreous) enamelled salt-glazed fireclay. 2/6. *Add.* April, 1952.

§540 : 1952 Glass (vitreous) enamelled salt-glazed fireclay pipes. 3/–. *Add.* Feb., 1953.

§556 : 1945 Cement concrete cylindrical pipes and tubes (not reinforced). 3/–. *Add.* Dec., 1949.

§1130 : 1943 Schedule of cast iron drain fittings, spigot and socket type. 4/–.

§1143 : 1943 Special salt-glazed ware pipes, with chemically resistant properties. 2/6.

§1194 : 1944 Concrete porous pipes for under drainage. 2/6.

§1196 : 1944 Clayware field drain pipes. 2/–.

§1211 : 1945 Centrifugally cast (spun) iron pipes for water, gas and sewage. 4/–.

§1247 : 1945 Manhole step irons. 2/6.

FLUE AND HEATING PIPES AND FITTINGS

40 : 1908 Cast iron low pressure heating pipes. 2/6.

§41 : 1946 Cast iron spigot and socket flue or smoke pipes. 2/6.

§567 : 1948 Asbestos cement flue pipes and fittings—light quality. 3/–. *Add.* Dec., 1950.

§715 : 1951 Sheet metal cylindrical flue pipes, fittings and accessories for gas fired appliances. 4/–.

§766 : 1938 Bafflers and draught diverters on gas appliances, including recommendations for flue terminals. 2/6. *Add.* May, 1938.

§835 : 1948 Asbestos cement flue pipes and fittings—heavy quality. 3/–. *Add.* Dec., 1950.

§1181 : 1944 Clay flue fittings and chimney pots suitable for open fires. 2/6.

B.S.

§1289 : 1945 Pre-cast concrete flue blocks for gas fires and ventilation. 3/–.

§1294 : 1946 Soot doors for domestic buildings. 2/–. *Add.* March, 1946.

RAINWATER, SOIL, WASTE AND VENTILATING PIPES AND FITTINGS

§416 : 1944 Cast iron spigot and socket soil, waste and ventilating pipes, fittings and accessories. 6/–. *Add.* Dec., 1949 and June, 1952.

§460 and §1205 : 1948 Cast iron rainwater goods. 5/–. *Add.* June, 1952.

§569 : 1949 Asbestos cement rainwater pipes, gutters and fittings. 6/–. *Add.* Dec., 1949.

§582 : 1948 Asbestos cement soil, waste and ventilating pipes and fittings. 5/–. *Add.* Jan., 1949.

§1091 : 1946 Pressed steel gutters, pipes, fittings and accessories. 2/6.

§1430 : 1947 Aluminium rainwater goods (cast and extruded). 2/6. *Add.* Aug., 1948 and July, 1949.

§1431 : 1948 Wrought copper and wrought zinc rainwater goods. 2/6. *Add.* Oct., 1951.

§1543 : 1949 Wrought aluminium rainwater goods. 2/6.

SUPPLY PIPES AND FITTINGS (GAS AND WATER)

§61 : Part 1 : 1947 Copper tubes (heavy gauge) for general purposes. 2/6.

§61 : Part 2 : 1946 Screw threads for copper tubes. 2/–. *Add.* April, 1948.

66 : 1914 Copper alloy three-piece unions for low and medium pressure screwed copper tubes. 3/–.

§78 : 1938 Cast iron pipes (vertically cast) for water, gas and sewage and special castings for use therewith. 12/6, including addendum P.D. 1166 weights of special castings, available separately if required, price 3/–. *Add.* Nov., 1938, Sept., 1943, Jan., 1948 and March, 1953.

B.S.

§99 : 1922 Copper alloy pipe fittings. 5/–. *Add.* Oct., 1927.

§143 : 1952 Malleable cast iron and copper alloy pipe fittings. 7/6.

§486 : 1933 Asbestos cement pressure pipes. 2/–.

§534 : 1934 Steel spigot and socket pipes and specials for water, gas and sewage. 5/–. *Add.* July, 1952.

§602 : 1949 Lead pipes (for other than chemical purposes). 2/6.

§603 : 1941 Lead pipes (B.N.F. ternary alloy No. 2). 2/6.

§659 : 1944 Light gauge copper tubes for water, gas and sanitation. 2/–. *Add.* May, 1946.

†674 : 1942 Rubber joint rings for water mains and sewers. 2/–. *Add.* Jan., 1945 and April, 1946.

§788 : 1938 Wrought iron tubes and tubulars, gas (light), water (medium), steam (heavy) qualities. 4/–. *Add.* March, 1938 and Jan., 1939.

§864 : 1945 Capillary fittings and compression fittings, of copper or copper alloy for use with light gauge copper tube. 2/6.

§1085 : 1946 Lead pipes. Silver-copper-lead alloy. 2/6. *Add.* June, 1947.

§1185 : 1944 Stoptap guard pipes. 2/–.

§1211 : 1945 Centrifugally cast (spun) iron pipes for water, gas and sewage. 4/–.

1218 : 1946 Sluice valves for waterworks purposes. 4/–. *Add.* Feb., 1950.

§1256 : 1952 Malleable cast iron (white-heart process) and cast copper alloy pipe fittings. 7/6.

§1304 : 1946 "Ready-to-fit" thermal insulating materials for hot and cold water supply and central heating installations for small dwellings. 2/–.

§1386 : 1947 Copper tubes to be buried underground. 2/–. *Add.* Oct. 1947.

§1387 : 1947 Steel tubes and tubulars suitable for screwing to B.S. 21 Pipe Threads. 2/6. *Add.* Feb., 1949, April, 1951 and Aug., 1951.

§1737 : 1951 Jointing materials and compounds for water, town gas and low-pressure steam installations. 5/–.

B.S.

§1740 : 1951 Wrought pipe fittings iron and steel (screwed B.S.P. thread). 5/–. *Add.* Aug., 1951.

§1775 : 1951 Steel tubes for mechanical, structural and general engineering purposes. 3/–.

1958 : 1953 Tools for soldered socket-spigot joints for lead and lead alloy pipes. 2/6.

1972 : 1953 Polythene tube for cold water services. 3/6.

APPLIANCES AND FITTINGS

ELECTRICITY APPLIANCES AND FITTINGS

7 : 1953 Rubber-insulated cables and flexible cords for electric power and lighting. 10/–.

31 : 1940 Steel conduits and fittings for electrical wiring. *Add.* Mar., 1942. 4/–.

52 : 1952 Dimensions of bayonet lamp-caps and lampholder plugs. 5/–.

67 : 1938 Ceiling roses, two- and three-terminal. 2/6.

88 : 1952 Electric fuses for circuits of voltage-ratings up to 660 volts. 6/–.

98 : 1947 Dimensions of screw lamp-caps and lampholders (Edison type). 2/6. *Add.* Sept., 1947, April, 1951, Jan., 1952 and July, 1952.

161 : 1940 Tungsten filaments general service electric lamps. 5/–. *Add.* Sept., 1942, Feb. 1943, March and July, 1946, July, 1947, Nov., 1948, Jan., 1952, March, 1952, Aug., 1952 and Jan., 1953.

214 : 1939 Distribution boards (up to 100 amperes per outgoing circuit and 250 volts to earth). 2/– *Add.* April, 1947 and Oct., 1949.

372 : 1930 Side entry wall plugs and sockets for domestic purposes, 2-pole. 3/–. (For 3-pole plugs and sockets see B.S. 546.) *Add.* March, 1933, April, 1934, Oct., 1938 and May, 1942.

438 : 1952 Cooker control units, for use in 2-wire circuits of not more than 250 volts declared voltage. 2/–.

B.S.

472 : 1932 Mains-operated synchronous clocks. 2/–.

480 : 1942 Metal sheathed, impregnated, paper insulated plain annealed copper conductors for electricity supply, including voltage tests, dimensions of. 5/–. *Add.* Feb., 1945, May, 1946 and Jan., 1947

546 : 1950 Two-pole and earthing-pin plugs socket outlets and socket-outlet adaptors. 3/–.

646 : 1935 Ordinary-duty 250-volt cartridge fuses (rated up to 5 amperes) for A.C. and D.C. service. 2/–.

732 : 1937 Inlet and outlet connectors for bell, telephone and similar circuits (excluding post office telephone circuits). Temporarily out of print.‡

774 : 1938 Under-floor steel ducts for electrical service with fittings. 3/–.

815 : 1938 Under-floor non-metallic ducts for electrical services with fittings. 4/–.

816 : 1952 Requirements for electrical applicances and accessories. 3/–.

820 : 1938 Grey cast iron circuit boxes for electrical wiring. 2/–.

832 : 1945 Bell transformers excluding transformers for use in mines. 2/–.

840 : 1939 Light-gauge seamless copper and copper-alloy conduit and fittings for electrical wiring 2/6.

841 : 1939 Lamp cars and lampholders for architectural lamps for voltages not exceeding 250 volts. 2/–. *Add.* Sept., 1942 and Jan., 1952.

861 : 1939 Air-break switches (including isolating switches, totally enclosed and flame-proof types) for voltages not exceeding 660 volts. 3/–. *Add.* May, 1946.

922 : 1950 Electrical refrigerators and food freezers for household use in all climates. 3/–.

951 : 1948 Earthing clamps. 2/6. *Add.* Nov., 1950.

1183 : 1944 Space required for domestic electrical appliances. 2/–. *Add.* Jan., 1946.

B.S.

1299 : Part 1 : 1946 Tumbler-switches and associated switch-plates and switch-boxes. Part 1, 5-ampere flush type. 2/–. *Add.* Nov., 1946, Dec., 1948 and April, 1951.

1315 : Part 1 : 1946 Domestic electric ovens, Part 1, cooking tests. 2/6. *Add.* Nov., 1946.

1326 : 1946 Free-standing circular domestic electric wash-boilers. 2/–. *Add.* April, 1948.

1327 : 1946 Insulated asbestos roved flexible cords. 2/–.

1361 : 1947 Cartridge-fuses for domestic consumers' units. 2/–. *Add.* March, 1951.

1362 : 1947 Cartridge fuse-links for use in plugs. 2/–. *Add.* July, 1947.

1363 : 1947 Fused-plugs and shuttered socket-outlets. 2/6. *Add.* June, 1947, Dec., 1948 and May, 1950.

1454 : 1948 Consumers' electricity control units. 3/–.

1555 : 1949 Thermostats for electrically-heated domestic hot water supply. (A.C. only.) 2/–. *Add.* May, 1950.

'1556 : 1949 Electric immersion heaters for domestic hot water supply. 2/–. *Add.* Feb., 1951.

1691 : 1950 Electrical refrigerators and food freezers for household use in temperate climates only. 3/–.

1833 : 1952 Cooker control units rated at 30 amperes, 250 volts single-phase A.C. only. 2/6. *Add.* Oct., 1952

2004 : 1953 Polyvinyl chloride insulated cables and flexible cords for electric power and lighting. 6/–.

FIRE APPLIANCES AND FITTINGS

138 : 1948 Portable fire extinguishers of the water type (soda acid). 2/6. *Add.* April, 1952.

336 : 1936 Fire hose couplings (including screwed outlets for hydrants, suction hose, couplings and branch pipes and nozzle connections). 3/–.

740 : Part 1 : 1948 Portable fire extinguishers of the foam type. 2/6. *Add.* April, 1952.

B.S.

740 : Part 2 : 1952 Portable fire extinguishers of the foam type (gas pressure). 6/–.

750 : 1950 Underground fire hydrants and dimensions of surface box openings. 2/–. *Add.* Nov., 1950 and April, 1951.

1382 : 1948 Portable fire extinguishers of the water type (gas pressure). 2/6. *Add.* April, 1952.

1641 : 1950 Cast iron pipe fittings for sprinklers. 2/6.

1689 : 1950 Fire buckets. 2/–. *Add.* Dec., 1952.

1721 : 1951 Portable fire extinguishers of the carbon tetrachloride type. 4/–. *Add.* Jan., 1953.

GAS APPLIANCES AND FITTINGS

570 : 1948 Plug-and-socket gas connectors for portable appliances. 2/6. *Add.* Aug., 1949.

669 : 1952 Flexible metallic tubing and connector ends for appliances burning town gas. 6/–.

746 : 1937 Gas meter unions. 3/–.

884 : 1941 Low-pressure gas mantles. 3/–.

1250 : Part 1 : 1945 Domestic gas appliances for immediate post-war housing. Part 1, general specification including space and rating requirements. 2/6. *Add.* Aug., 1946.

1250 : Part 2 : 1946 Domestic gas appliances for immediate post-war housing. Part 2, detailed requirements in regard to cookers, water heaters, gas fires, space heaters and refrigerators. 4/–. *Add.* Sept., 1951.

1381 : 1947 Gas lighting units and fittings for single-family dwellings. 2/6.

§1396 : 1947 Gas meter cupboards. 2/–.

1401/3 : 1947 Copper and brass tubes for gas installation work and gas lighting. 2/–. *Add.* June, 1948.

1552 : 1950 Control plug cocks for low pressure gas. 2/–.

1945 : 1953 Fireguards for heating appliances. 2/–. *Add.* June, 1953.

B.S.

IRONMONGERY

§455 : 1945 Schedule of sizes for locks and latches for doors. 3/6. *Add.* Dec., 1946.

606 : 1935 Plaited sash lines. 2/-.

§1202 : 1944 Wire nails and cut nails for building purposes. 2/-. *Add.* July, 1949.

§1210 : 1952 Wood screws. 3/-.

§1227 : 1945 Hinges. 4/-.

§1228 : 1945 Iron, steel and non-ferrous door bolts. 2/6. *Add.* Jan., 1946.

§1331 : 1946 Builders' hardware for housing. 6/-. *Add.* Jan., 1947.

§1373 : 1947 Clothes-line posts. 2/-.

1485 : 1948 Galvanised wire netting. 2/-.

§1494 : 1951 Fixing accessories for building purposes. 7/6.

KITCHEN FITTINGS

§1195 : 1948 Kitchen fitments and equipment. 6/-. *Add.* July, 1952.

SANITARY APPLIANCES AND FITTINGS

219 : 1949 Soft solders. 2/-.

441 : 1935 Cored solder. Temporarily out of print.‡

§504 : 1944 Drawn lead traps. 2/6. *Add.* April, 1945.

§1010 : 1953 Draw-off taps and stopvalves for water services (screw-down pattern). 6/-.

§1125 : 1945 Flushing cisterns for water closets. 2/-. *Add.* Nov., 1946, Aug., 1948 and April, 1952.

§1182 : 1944 Non-ferrous thimbles and ferrules. 2/-. *Add.* May, 1947.

§1184 : 1951 Copper and copper alloy traps and wastes. 3/-.

§1185 : 1944 Stop-tap guard pipes. 2/-.

§1188 : 1944 Ceramic lavatory basins. 2/6.

§1189 : 1944 Cast iron baths for domestic purposes (dimensions and workmanship). 2/-. *Add.* July, 1946 and Sept., 1947.

§1206 : 1945 Fireclay sinks (dimensions and workmanship). 2/6. *Add.* Jan., 1952.

§1212 : 1946 Ball valves ("Portsmouth" type). 5/-. *Add.* Sept., 1948 and April, 1949.

B.S.

§1213 : 1945 Ceramic washdown W.C. pans (dimensions and workmanship). 2/-. *Add.* April, 1948.

§1226 : 1945 Draining boards. 2/-. *Add.* Oct., 1945 and Dec., 1951.

§1229 : 1945 Fireclay wash tubs and sink sets. 2/-. *Add.* April, 1952.

§1244 : 1945 Metal sinks. 2/-. *Add.* Sept., 1947.

§1254 : 1945 W.C. seats (plastics). 1/-. *Add.* June, 1952.

§1255: 1953 Brackets and supports for lavatory basins and sinks. 2/6.

§1291 : 1946 Ferrous traps for baths. 2/6.

§1329 : 1946 Metal lavatory basins. 2/-. *Add.* Sept., 1947.

§1390 : 1947 Sheet steel baths for domestic purposes. 2/-. *Add.* April, 1948.

§1415 : 1947 Mixing valves (manually operated) for ablutionary and domestic purposes. 2/-.

1876 : 1952 Automatic flushing cisterns for urinals. 2/-.

1968 : 1953 Floats for ball valves (copper). 3/6.

SOLID-FUEL APPLIANCES AND FITTINGS

§758 : 1945 Small domestic hot water supply boilers for solid fuel. 3/6.

§779 : 1938 Cast iron boilers for central heating and hot water supply. 2/6. *Add.* Nov., 1939.

§780 : 1938 Riveted steel boilers for hot water central heating and hot water supply. 4/-. *Add.* Nov., 1939.

§1251 : 1945 Open fires for domestic purposes. 3/-. *Add.* June, 1949.

§1252 : 1945 Solid fuel cookers and combination grates. 2/-.

§1304 : 1946 "Ready-to-fit" thermal insulating materials for hot and cold water supply and central heating installations for small dwellings. 2/-.

§1334 : 1947 Preformed thermal insulating materials for central heating and hot and cold water supply installations. 3/6.

1588 : 1949 Thermal insulating materials suitable for use within the temperature range 200° F. to 450° F. 5/-.

B.S.

§1589 : 1950 Thermal insulating materials, plastic composition flexibel and loose-fill. 2/–.

§1785 : 1951 Thermal insulating materials for buildings. 2/6.

WATER-SUPPLY APPLIANCES AND FITTINGS

§417 : 1951 Galvanised mild steel cisterns, tanks and cylinders. 2/6. *Add.* July, 1952.

§699 : 1951 Copper cylinders for domestic purposes. 2/6.

§853 : 1939 Calorifiers. 6/–.

§1010 : 1953 Draw-off taps and stop valves for water services (screw-down pattern.) 6/–.

§1208 : 1945 Semi-rotary pumps, hand operated double acting, for water. 2/–.

1563 : 1949 Cast-iron sectional tanks (rectangular). 5/–.

1564 : 1949 Pressed steel sectional tanks (rectangular). 3/–.

§1565 : 1949 Galvanised mild-steel indirect cylinders. 2/6.

§1566 : 1949 Copper indirect cylinders. 3/–.

FINISHES

§144 : 1936 Coal tar creosote for the preservation of timber (types A, A2 and B). 2/6. *Add.* Feb., 1941.

§256 : 1936 Varnishes. 3/6.
Including :
B.S. 256. Interior oil varnish.
B.S. 257. Exterior oil varnish.
B.S. 258. Flatting or rubbing oil varnish.
B.S. 274. Extra hard drying varnish.

§261 : 1936 Ready mixed paints (oil gloss). 3/6. *Add.* Oct., 1939 and Dec., 1940.
Including :
B.S. 261. White (white lead base).
B.S. 262. Tinted (white lead base).
B.S. 277. White (zinc oxide base).
B.S. 278. Tinted (zinc oxide base).
B.S. 293. Green.
B.S. 294. Black.
B.S. 295. Red oxide of iron.
B.S. 371. Purple brown oxide of iron.

B.S.

§381C : 1948 Colours for ready mixed paints. (Revised and amplified edition containing 97 colours.) 5/–.
Individual colour specimens (5 in. by 2 in.), on cards (5 in. by 8 in.), price 1/6 each, or sets of the complete 97 colours in a carton, £5.

544 : 1934 Linseed oil putty (for wooden frames). 2/–. *Add.* Dec., 1940.

§913 : 1940 Pressure creosoting of timber. 2/–.

§929 : 1947 Ready mixed oil paints. 2/6.

§1011 : 1942 Red lead ready mixed paints. 2/–. *Add.* March, 1942.

†§1033 : 1942 Priming paint (lead base) for the protection of steel sheet. 2/–. *Add.* May, 1942.

§1053 : 1950 Water paints and distempers for interior use. 2/6.

†§1070 : 1942 Black paint (tar base) for use on iron and steel. 2/–.

§1215 : 1945 Oil stains. 2/–.

§1224 : 1945 Electroplated coatings of nickel and chromium on steel and brass. 3/–. *Add.* Jan., 1947 and Jan., 1951.

§1248 : 1945 Wall papers. 2/6. *Add.* Feb., 1946.

§1282 : 1945 Classification of wood preservatives. 2/6. *Add.* July, 1947.

§1323 : 1946 Synthetic-resin bonded-paper sheet (thermosetting) for use in the building industry. 2/–.

§1336 : 1946 Knotting. 2/–.

1344 : 1947 Methods of testing vitreous enamel finishes. 2/–.

§1358 : 1947 Colours for vitreous enamel finishes. 2/–. *Add.* Sept., 1947.

§1448 : 1948 Nomenclature of decorative metallic finishes. 2/6.

§1572 : 1949 B.S. flat colours for wall decoration. Specimen colours to B.S. 1572 : 1949 available 1/– each or 10/– the set of fifteen colours.

§1706 : 1951 Electroplated coatings of cadmium and zinc on iron and steel. 2/6.

2015 : 1953 Glossary of paint terms. 6/–.

P.D. 420 : 1953 Methods of protection against corrosion for light-gauge steel used in building. 3/–.

B.S.

REFUSE DISPOSAL

§792 : 1947 Mild steel dustbins. 2/6. *Add.* May, 1948.

§1136 : 1943 Refuse storage containers. 2/–.

§1577 : 1949 Mild steel refuse or food waste containers. 2/–.

§1703 : 1951 Refuse chutes for multi-storey buildings. 2/–.

BUILDERS' PLANT EQUIPMENT

Handbook No. 4, British Standards for Lifting Tackle, price 12/6. Includes 21 British Standards for fibre and wire ropes, chains and terminal fittings, together with extracts from other standards relating to the materials from which the fittings are made.

327 : Part 1 : 1951 Power-driven derrick cranes. 6/–.

327 : Part 2 : 1933 Derrick cranes (hand operated). 4/–. *Add.* March, 1942.

328 : 1950 Twist drills and centre drills. 6/–.

329 : 1951 Round strand steel wire suspension ropes for lifts and hoists. 3/–.

257 : 1930 Travelling jib cranes (contractor's type). 3/–. *Add.* Dec., 1941.

394 : 1951 Short link wrought iron chain (excluding pitched or calibrated chain). 2/–.

431 : 1946 Manila ropes for general purposes. 2/6.

673 : 1950 Pneumatic tools and accessories. 3/–.

781 : 1950 Wrought iron chain slings and rings, links alternative to rings egg links and intermediate links. 6/–.

825 : 1949 Mild steel shackles. 5/–.

871 : 1939 Abrasive papers and cloths for general purposes. 4/–.

876 : 1949 Hand hammers. 3/6.

908 : 1946 : Sisal ropes for general purposes. 3/–.

†1129 : 1943 Timber ladders. 2/–.

1139 : 1951 Metal scaffolding. 5/–.

1305 : 1946 Batch type concrete mixers. 2/–. *Add.* July, 1946 and Jan., 1951.

1421 : 1947 Picks, beater picks and mattocks. 2/–. *Add.* Dec., 1948.

B.S.

1623 : 1950 Hand-rollers for road and constructional engineering. 2/–.

1692 : 1950 Gin blocks for fibre rope. 2/–.

1757 : 1951 Power-driven mobile cranes. 6/–.

1761 : 1951 Single bucket excavators, of the crawler-mounted friction-driven type. 6/–.

1786 : 1951 Steel wheelbarrows (building contractors' general purpose type). 1/6.

1857 : 1952 Pipe cutters. 3/6.

1943 : 1953 Woodworking chisels and gouges. 4/–.

1978 : 1953 Bit braces. 3/–.

2037 : 1953 Aluminium alloy ladders, steps and trestles for the building and civil engineering industries. 2/6.

See also Mechanical Engineering sectional list.

FENCING

1485 : 1948 Galvanised wire netting. 2/–.

§1722 Fencing,

Part 1 : 1951 Chain link fences. 3/–.

Part 2 : 1951 Woven wire fences. 3/–.

Part 3 : 1951 Strained wire fences. 3/–.

Part 4 : 1951 Cleft chestnut pale fences. 3/–.

Part 5 : 1951 Close-boarded fences, including oak pale fences. 3/–.

Part 6 : 1951 Wooden palisade fences. 3/–.

Part 7 : 1951 Wooden post and rail fences. 3/–. *Add.* Aug., 1952.

Part 8 : 1951 Mild steel or wrought iron continuous bar fences. 3/–.

Part 9 : 1951 Mild steel or wrought iron unclimbable fences. 3/–.

CYCLE STANDS

1716 : 1951 Cycle stands. 2/6.

ROAD, PATH AND PLAYGROUND MATERIALS

See special sectional list, Road Engineering.

SPECIAL SERIES FOR SCHOOLS, BS/MOE

BS/MOE 1–7. Sanitary equipment, including:

BS/MOE 1 Fireclay basins and ancillary equipment.
2 Fireclay lavatory troughs.
3 Fireclay drinking fountains.
4 Fireclay sinks, tubs, footbaths and slop hoppers.
5 Fireclay trays for individual shower baths.
6 Fireclay urinal ranges and ancillary equipment.
7 W.C. suites with fireclay pans.

1 volume: 7/6.

BS/MOE 11-22 : 1950 School Furniture. 17/6.

BS/MOE 26–29 : 1947 Cloakroom equipment for schools (including W.C. and shower partitions). 7/6.

GYMNASIUM EQUIPMENT

1892 : 1952 Gymnasium equipment. 12/6.

CODES OF PRACTICE

Codes issued by the B.S.I. for the Council for Codes of Practice for Buildings (formed under the aegis of the Ministry of Works).

CP. 3—Chapter I (A) : 1949 Daylight (dwellings and schools.). 5/–.

CP 3—Chapter I (B) : 1945 Sunlight (houses, flats and schools only). 6*d.*

CP 3—Chapter I (C) : 1950 Ventilation. 2/6.

CP. 3—Chapter III : 1948 Sound insulation (houses, flats and schools). 2/–.

CP. 3—Chapter IV : 1948 Precautions against fire (houses and flats of not more than two storeys). 2/–.

CP 3—Chapter V : 1952 Loading. 4/–.

CP. 3—Chapter VII (F) : 1945 Provision of artificial light (houses, flats and schools only). 2/–. *Add.* Aug., 1952.

CP 3—Chapter VII : 1950 Engineering and utility services. 4/–.

CP. 3—Chapter VIII : 1949 Heating and thermal insulation. 2/–.

CP. 3—Chapter IX : 1950 Durability. 4/–.

CP. 3—Chapter X : 1950 Precautions against vermin and dirt. 1/–.

CP. 101 : 1948 Foundations and substructures for houses, flats and schools of not more than two storeys. 2/–.

CP. 111 : 1948 Structural recommendations for load-bearing walls. 5/–.

CP. 112 : 1952 The structural use of timber in buildings. 10/6.

CP. 112.100 : 1952 Preservative treatments for timber in buildings (included in CP. 112 but available separately). 3/–.

CP. 113 : 1948 The structural use of steel in buildings. 7/–.

CP. 113.102 : 1951 Arc-welded construction. 5/–.

CP. 113.201 : 1953 The structural use of steel tubes in buildings. 5/–.

CP. 114 : 1948 The structural use of normal reinforced concrete in buildings. 5/–. *Add.* Feb., 1949.

CP. 114.100 – 114.105 : 1950 Suspended concrete floors and roofs (including stairs). 6/–. *Add.* June, 1950.

CP. 121.101 : 1951 Brickwork. 6/–. *Add.* Nov., 1952.

CP. 121.201 : 1951 Masonry. Walls ashlared with natural or cast stone. 6/–.

CP. 121.202 : 1951 Masonry. Rubble walls. 7/6.

CP. 122 : 1952 Walls and partitions of blocks and slabs. 9/–.

CP. 123.101 : 1951 Dense concrete walls. 4/–. *Add.* Nov., 1951 and June, 1952.

CP. 131.101 : 1951 Flues for domestic appliances. 5/–. *Add.* July, 1952.

CP. 142 : 1951 Slating and tiling. 5/–. *Add.* Oct., 1951.

CP. 143.104 : 1951 Copper coverings for roofs. 4/–.

CP. 143.201 : 1951 Asbestos-cement sheet roof coverings. 3/6. *Add.* March, 1952.

CP 144.101 : 1952 Bitumen felt roof coverings. 5/–.

CP 144.201 : 1952 Mastic asphalt roofing. 5/6.

CP. 145.101 : 1951 Patent glazing. 2/–.

CP. 201 : 1951 Timber flooring. 3/–.

CP. 202 : 1951 Tile flooring and slab flooring. 3/–. *Add.* Dec., 1952.

CP. 203 : 1951 Sheet and similar floorings. 3/–. *Add.* Oct., 1951.

CP. 204 : 1951 In-situ flooring. 7/6.

CP. 211 : 1949 Internal plastering. 10/–.

CP. 231 : 1952 Painting. 10/–.

CP. 301 : 1950 Building drainage. 7/–.

CP. 302.200 : 1949 Cesspools. 2/–.

CP. 303 : 1952 Surface water and sub-soil drainage. 2/–.

CP. 305 : 1952 Sanitary appliances. 3/–.

CP. 310 : 1952 Water supply. 10/–.

CP. 321 : 1948 Electrical installations. 10/– *Add.* Dec., 1951.

CP. 321.101 : 1949 Electric wiring systems 4/–. *Add.* Dec., 1951.

CP. 321.102 : 1950 Installation and maintenance of electrical machines, transformers, rectifiers, capacitors and associated equipment. 4/–.

CP. 322.101 : 1947 Provision of electricity service cables for small houses. 1/–.

CP. 322.102 : 1948 Electricity supply intake arrangements for flats and other multi-occupier buildings. 2/–.

CP. 322.103 : 1948 Installation of consumers' electricity supply controls for small dwellings (for A.C. systems). 2/–.

CP. 323 : 1948 Code of practice for private electric generating plant. 2/–.

CP. 324.101 : 1948 The provision of electric lighting in dwellings. 2/–.

CP. 324.102 : 1948 Provision of electric lighting in schools. 2/–.

CP. 324.201 : 1948 Installation of domestic electric space heating equipment. 2/–.

CP. 324.202 : 1951 Electric water heating installations. 3/–.

CP. 324.301 : 1948 Selection and installation of domestic electric cookers. 2/–.

CP. 324.403 : 1948 Installation of vapour compression type domestic electric refrigerators. 2/–.

CP. 326.101 : 1948 Protection of structures against lightning. 5/–.

CP. 327.101 : 1952 Telephones and telegraphs—public services. 7/6.

CP. 327.102 : 1952 Telephones and telegraphs—private services. 7/6.

CP. 327.201 : 1951 Broadcast reception. 6/–.

CP. 327.300 : 1952 Sound distribution systems. 6/–.

CP. 327.401 : 1952 Bell and call systems. 3/–.

CP. 327.402 : 1951 Staff location systems. 3/–.

CP. 327.403 : 1952 Impulse clock and timing systems. 3/–.

CP. 327.404/402.501 : 1951 Electrical fire alarms. 5/–.

CP. 331.101 : 1947 Gas service pipes. 2/–.

CP. 331.102 : 1947 Gas metering and consumers' control. 2/–.

CP. 331.103 : 1947 Gas installation pipes. 2/–.

CP. 331.104 : 1947 Code for flues for gas applicances. 2/–.

CP. 332.101 : 1947 Gas lighting — single family dwellings. 3/6.

CP. 332.201 : 1947 Domestic hot water supply by gas—single family dwellings. 3/–.

CP. 332.202 : 1948 Domestic hot water supply by gas (schools). 5/–.

CP. 332.301 : 1947 Space heating by means of independent gas appliances. 3/6.

CP. 332.303 : 1951 Installation of gas fired boilers for central heating and hot water. 3/–.

CP. 332.401 : 1947 Gas cooking installations —single family dwellings. 2/–.

CP. 332.501 : 1947 Gas-operated refrigerators. 2/–.

CP. 332.601 : 1947 Installation of gas-heated appliances for laundering and ancillary domestic purposes. 2/–.

CP. 342 : 1950 Centralised domestic hot water supply. 12/6. *Add.* April, 1951 and July, 1952.

CP. 402.101 : 1952 Hydrant systems. 2/–.

CP. 402.201 : 1952 Sprinkler systems. 2/–.

CP. 402.401 : 1951 Portable fire extinguishers. 2/–.

CP. 403.101 : 1952 Small boiler systems using solid fuel. 4/–.

CP. 403 : 1952 Open fires, heating stoves and cookers burning solid fuel. 7/–.

CP. 406 : 1952 Mechanical refrigeration. 5/–.

CP. 407.101 : 1951 Electric lifts for passengers, goods and service. 4/–.

CP. 407.301 : 1950 Hand-power lifts for passengers, goods and service. 3/–.

CP. 412 : 1953 Installation of optical projection equipment in educational establishments. 7/6.

CP. 413 : 1951 Design and construction of ducts for services. 3/–. *Add* May, 1952.

ISSUES OF GENERAL INTEREST

B.S.

350 : 1944 Conversion factors and tables. 10/6. *Add.* April, 1949, Feb., 1952, June, 1952. (Including Addendum No. 1, PD. 957, available separately if required, price 2/–).

600 : 1935 Application of statistical methods to industrial standardisation and quality control. By Dr. E. F. Pearson. 15/–.

1000 — Universal decimal classification (for detailed particulars, see separate list).

1219 : 1945 Printers' and authors' proof corrections. 2/6. *Add.* April, 1950.

1219C : 1945 Table of symbols for printers' and authors' proof corrections. 1/–.

1313 : 1947 Fraction-defective Charts for quality control. 6/–.

1638 : 1950 Report on the selection of ranges of types and sizes (preferred numbers). 3/–.

PD.488 : 1946 Memorandum on sampling clauses in specifications for manufactured articles. 1/–.

The following lists of British Standards are available on application :

Aircraft
Automobile Engineering
Building
Chemical Engineering
Chemicals, Fats, Oils, Scientific Apparatus
Cinematography and Photography
Coal, Coke and Colliery Requisites
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YEARBOOK

B.S.I. Yearbook includes subject index and abstract of every British Standard issued. 12/6.

DRAFT CODES

Drafts of the following Codes have been circulated for comment by the B.S.I. for the Council for Codes of Practice for Buildings. Copies of these drafts are available from the B.S.I. at the prices indicated.

B.S.I. reference No. of draft.*	Title of code.	Code No.	Price.
CP(B) 631	Framed partitions	124	10/-
CP(B) 848	Gas cooking installations (schools)	332.402	2/-
CP(B) 869	Farm and horticultural electrical installations (*out of print*)	325	9/-
CP(B) 982	Board and sheet coverings (external)	124.200, 124.204 and 124.207	10/-
CP(B) 986	Timber coverings (internal), cork slab coverings (internal) and rigid infillings for framed partitions	124.301 124.309 and 124.401	5/-
CP(B) 1056	Soil and waste pipes above ground	304	5/-
CP(B) 1057	Wooden doors	151.101	5/-
CP(B) 1107	Central heating by low pressure hot water	341.300	15/-
CP(B) 1113	Small sewage treatment works	302.100	5/-

* *Reference numbers when ordering.* When ordering copies of *draft* codes, the B.S.I. reference number and not the code number should be quoted.

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